EXPRESS MAIL LABEL NO. EL387347783US
Attorney Docket No. SONY-747US

PATENT COOPERATION TREATY

RECEIVED

AUG 10 2000

PCT Limbach & Limbach

From the INTERNATIONAL SEARCHING AUTHORITY

To:
LIMBACH & LIMBACH L.L.P.
Attn. SUMMUT, Charles P.
2001 Ferry Building
SAN FRANCISCO,CALIFORNIA 94111
UNITED STATES OF AMERICA

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL SEARCH REPORT OR THE DECLARATION

(PCT Rule 44.1)

	Date of mailing (*day/month/year*) 08/08/2000
Applicant's or agent's file reference ~~SONY-T0747~~ SONY-747PC	**FOR FURTHER ACTION** See paragraphs 1 and 4 below
International application No. PCT/US 00/11504	International filing date (*day/month/year*) 28/04/2000
Applicant SONY CORPORATION et al.	Due 10/8/00

1. [X] The applicant is hereby notified that the International Search Report has been established and is transmitted herewith.

Filing of amendments and statement under Article 19:
The applicant is entitled, if he so wishes, to amend the claims of the International Application (see Rule 46):

When? The time limit for filing such amendments is normally 2 months from the date of transmittal of the International Search Report; however, for more details, see the notes on the accompanying sheet.

Where? Directly to the International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland
Fascimile No.: (41-22) 740.14.35

For more detailed instructions, see the notes on the accompanying sheet.

2. [ ] The applicant is hereby notified that no International Search Report will be established and that the declaration under Article 17(2)(a) to that effect is transmitted herewith.

3. [ ] **With regard to the protest** against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:

[ ] the protest together with the decision thereon has been transmitted to the International Bureau together with the applicant's request to forward the texts of both the protest and the decision thereon to the designated Offices.

[ ] no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. **Further action(s):** The applicant is reminded of the following:

Shortly after **18 months** from the priority date, the international application will be published by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau as provided in Rules 90*bis*.1 and 90*bis*.3, respectively, before the completion of the technical preparations for international publication.

Within **19 months** from the priority date, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase until 30 months from the priority date (in some Offices even later).

Within **20 months** from the priority date, the applicant must perform the prescribed acts for entry into the national phase before all designated Offices which have not been elected in the demand or in a later election within 19 months from the priority date or could not be elected because they are not bound by Chapter II.

Name and mailing address of the International Searching Authority	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Shantisaroop Pherai

NOTES TO FORM PCT/ISA/220

These Notes are intended to give the basic instructions concerning the filing of amendments under article 19. The Notes are based on the requirements of the Patent Cooperation Treaty, the Regulations and the Administrative Instructions under that Treaty. In case of discrepancy between these Notes and those requirements, the latter are applicable. For more detailed information, see also the PCT Applicant's Guide, a publication of WIPO.

In these Notes, "Article", "Rule", and "Section" refer to the provisions of the PCT, the PCT Regulations and the PCT Administrative Instructions respectively.

INSTRUCTIONS CONCERNING AMENDMENTS UNDER ARTICLE 19

The applicant has, after having received the international search report, one opportunity to amend the claims of the international application. It should however be emphasized that, since all parts of the international application (claims, description and drawings) may be amended during the international preliminary examination procedure, there is usually no need to file amendments of the claims under Article 19 except where, e.g. the applicant wants the latter to be published for the purposes of provisional protection or has another reason for amending the claims before international pbulication. Furthermore, it should be emphasized that provisional protection is available in some States only.

What parts of the international application may be amended?

Under Article 19, only the claims may be amended.

During the international phase, the claims may also be amended (or further amended) under Article 34 before the International Preliminary Examining Authority. The description and drawings may only be amended under Article 34 before the International Examining Authority.

Upon entry into the national phase, all parts of the international application may be amended under Article 28 or, where applicable, Article 41.

When? Within 2 months from the date of transmittal of the international search report or 16 months from the priority date, whichever time limit expires later. It should be noted, however, that the amendments will be considered as having been received on time if they are received by the International Bureau after the expiration of the applicable time limit but before the completion of the technical preparations for international publication (Rule 46.1).

Where not to file the amendments?

The amendments may only be filed with the International Bureau and not with the receiving Office or the International Searching Authority (Rule 46.2).

Where a demand for international preliminary examination has been/is filed, see below.

How? Either by cancelling one or more entire claims, by adding one or more new claims or by amending the text of one or more of the claims as filed.

A replacement sheet must be submitted for each sheet of the claims which, on account of an amendment or amendments, differs from the sheet originally filed.

All the claims appearing on a replacement sheet must be numbered in Arabic numerals. Where a claim is cancelled, no renumbering of the other claims is required. In all cases where claims are renumbered, they must be renumbered consecutively (Administrative Instructions, Section 205(b)).

The amendments must be made in the language in which the international application is to be published.

What documents must/may accompany the amendments?

Letter (Section 205(b)):

The amendments must be submitted with a letter.

The letter will not be published with the international application and the amended claims. It should not be confused with the "Statement under Article 19(1)" (see below, under "Statement under Article 19(1)").

The letter must be in English or French, at the choice of the applicant. However, if the language of the international application is English, the letter must be in English; if the language of the international application is French, the letter must be in French.

The letter must indicate the differences between the claims as filed and the claims as amended. It must, in particular, indicate, in connection with each claim appearing in the international application (it being understood that identical indications concerning several claims may be grouped),whether

(i) the claim is unchanged;

(ii) the claim is cancelled;

(iii) the claim is new;

(iv) the claim replaces one or more claims as filed;

(v) the claim is the result of the division of a claim as filed.

The following examples illustrate the manner in which amendments must be explained in the accompanying letter:

1. [Where originally there were 48 claims and after amendment of some claims there are 51]:
"Claims 1 to 29, 31, 32, 34, 35, 37 to 48 replaced by amended claims bearing the same numbers; claims 30, 33 and 36 unchanged; new claims 49 to 51 added."

2. [Where originally there were 15 claims and after amendment of all claims there are 11]:
"Claims 1 to 15 replaced by amended claims 1 to 11."

3. [Where originally there were 14 claims and the amendments consist in cancelling some claims and in adding new claims]:
"Claims 1 to 6 and 14 unchanged; claims 7 to 13 cancelled; new claims 15, 16 and 17 added." or
"Claims 7 to 13 cancelled; new claims 15, 16 and 17 added; all other claims unchanged."

4. [Where various kinds of amendments are made]:
"Claims 1-10 unchanged; claims 11 to 13, 18 and 19 cancelled; claims 14, 15 and 16 replaced by amended claim 14; claim 17 subdivided into amended claims 15, 16 and 17; new claims 20 and 21 added."

"Statement under article 19(1)" (Rule 46.4)

The amendments may be accompanied by a statement explaining the amendments and indicating any impact that such amendments might have on the description and the drawings (which cannot be amended under Article 19(1)).

The statement will be published with the international application and the amended claims.

It must be in the language in which the international appplication is to be published.

It must be brief, not exceeding 500 words if in English or if translated into English.

It should not be confused with and does not replace the letter indicating the differences between the claims as filed and as amended. It must be filed on a separate sheet and must be identified as such by a heading, preferably by using the words "Statement under Article 19(1)."

It may not contain any disparaging comments on the international search report or the relevance of citations contained in that report. Reference to citations, relevant to a given claim, contained in the international search report may be made only in connection with an amendment of that claim.

Consequence if a demand for international preliminary examination has already been filed

If, at the time of filing any amendments under Article 19, a demand for international preliminary examination has already been submitted, the applicant must preferably, at the same time of filing the amendments with the International Bureau, also file a copy of such amendments with the International Preliminary Examining Authority (see Rule 62.2(a), first sentence).

Consequence with regard to translation of the international application for entry into the national phase

The applicant's attention is drawn to the fact that, where upon entry into the national phase, a translation of the claims as amended under Article 19 may have to be furnished to the designated/elected Offices, instead of, or in addition to, the translation of the claims as filed.

For further details on the requirements of each designated/elected Office, see Volume II of the PCT Applicant's Guide.

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference SONY-T0747	**FOR FURTHER ACTION** see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.	
International application No. PCT/US 00/ 11504	International filing date *(day/month/year)* 28/04/2000	(Earliest) Priority Date *(day/month/year)* 28/04/1999
Applicant SONY CORPORATION et al.		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 3 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

   a. With regard to the **language**, the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

   [ ] the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

   b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing :

   [ ] contained in the international application in written form.
   [ ] filed together with the international application in computer readable form.
   [ ] furnished subsequently to this Authority in written form.
   [ ] furnished subsequently to this Authority in computer readble form.
   [ ] the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
   [ ] the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

2. [ ] **Certain claims were found unsearchable** (See Box I).

3. [ ] **Unity of invention is lacking** (see Box II).

4. With regard to the **title**,

   [ ] the text is approved as submitted by the applicant.
   [X] the text has been established by this Authority to read as follows:

   METHODS AND APPARATUS FOR COLOR DEVICE CHARACTERIZATION

5. With regard to the **abstract**,

   [X] the text is approved as submitted by the applicant.
   [ ] the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is Figure No. 5

   [X] as suggested by the applicant.
   [ ] because the applicant failed to suggest a figure.
   [ ] because this figure better characterizes the invention.

   [ ] None of the figures.

INT[redacted]NATIONAL SEARCH REPORT

[redacted]ernational Application No
[redacted]CT/US 00/11504

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04N9/64 H04N9/68

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

PAJ, WPI Data, INSPEC, EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 720 390 A (MATSUSHITA ELECTRIC IND CO LTD) 3 July 1996 (1996-07-03) page 1, line 1 -page 2, line 19; figures 1,2 page 4, line 1 - line 52; figures 3-4B --- -/--	1,4,10, 19,24, 27,33, 47,50, 65,70, 73,79, 88,95,96

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
2 August 2000	08/08/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Fuchs, P

1

International Application No
PCT/US 00/11504

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	PATENT ABSTRACTS OF JAPAN vol. 016, no. 551 (P-1453), 20 November 1992 (1992-11-20) & JP 04 208928 A (OLYMPUS OPTICAL CO LTD), 30 July 1992 (1992-07-30) abstract ---	1,2,4,5, 10,11, 19,24, 25,27, 28,33, 34,47, 48,50, 51,56, 57,65, 70,71, 73,74, 79,80, 88,95,96
A	US 5 376 963 A (ZORTEA ANTHONY E) 27 December 1994 (1994-12-27) the whole document -----	1,4,10, 19,24, 27,33, 47,50, 65,70, 73,79, 88,95,96

1

INT NATIONAL SEARCH REPORT

ation on patent family members

ernational Application No
CT/US 00/11504

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
EP 0720390	A	03-07-1996	US	5548697	A	20-08-1996
			DE	69517401	D	13-07-2000
			JP	8256349	A	01-10-1996
JP 04208928	A	30-07-1992	NONE			
US 5376963	A	27-12-1994	DE	69424464	D	21-06-2000
			EP	0618737	A	05-10-1994
			JP	6295293	A	21-10-1994
			US	5376962	A	27-12-1994

EXPRESS MAIL LABEL NO. EL387347783US
Attorney Docket No. SONY-747US

PCT/US00/11504

PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF RECEIPT OF RECORD COPY

(PCT Rule 24.2(a))

To:

RECEIVED
JUL 1 7 2000
LIMBACH & LIMBACH L.L.P.

~~SUMMUT, Charles, P.~~
Limbach & Limbach L.L.P.
2001 Ferry Building
San Francisco, CA 94111
ETATS-UNIS D'AMERIQUE

Date of mailing (day/month/year) 05 July 2000 (05.07.00)	**IMPORTANT NOTIFICATION**
Applicant's or agent's file reference ~~SONY T0747~~ Sony 747PC	**International application No.** PCT/US00/11504 20mo date 12/28/00 30mo date 10/28/01 on cal

The applicant is hereby notified that the International Bureau has received the record copy of the international application as detailed below.

Name(s) of the applicant(s) and State(s) for which they are applicants:

SONY CORPORATION (for all designated States except US)
NISHIO, Kenichi et al (for US)

International filing date : 28 April 2000 (28.04.00)

Priority date(s) claimed : 28 April 1999 (28.04.99)

Date of receipt of the record copy by the International Bureau : 09 June 2000 (09.06.00)

List of designated Offices :

EP :AT,BE,CH,CY,DE,DK,ES,FI,FR,GB,GR,IE,IT,LU,MC,NL,PT,SE
National :JP,US

ATTENTION

The applicant should carefully check the data appearing in this Notification. In case of any discrepancy between these data and the indications in the international application, the applicant should immediately inform the International Bureau.

In addition, the applicant's attention is drawn to the information contained in the Annex, relating to:

- [X] time limits for entry into the national phase
- [X] confirmation of precautionary designations
- [X] requirements regarding priority documents

A copy of this Notification is being sent to the receiving Office and to the InternationalSearching Authority.

The International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland

Facsimile No. (41-22) 740.14.35

Authorized officer:
V. Gross VG

Telephone No. (41-22) 338.83.38

ANNEX TO FORM PCT/IB/301

International application No.
PCT/US00/11504

INFORMATION ON TIME LIMITS FOR ENTERING THE NATIONAL PHASE

The applicant is reminded that the "national phase" must be entered before each of the designated Offices indicated in the Notification of Receipt of Record Copy (Form PCT/IB/301) by paying national fees and furnishing translations, as prescribed by the applicable national laws.

The time limit for performing these procedural acts is **20 MONTHS** from the priority date or, for those designated States which the applicant elects in a demand for international preliminary examination or in a later election, **30 MONTHS** from the priority date, provided that the election is made before the expiration of 19 months from the priority date. Some designated (or elected) Offices have fixed time limits which expire even later than 20 or 30 months from the priority date. In other Offices an extension of time or grace period, in some cases upon payment of an additional fee, is available.

In addition to these procedural acts, the applicant may also have to comply with other special requirements applicable in certain Offices. **It is the applicant's responsibility** to ensure that the necessary steps to enter the national phase are taken in a timely fashion. Most designated Offices do not issue reminders to applicants in connection with the entry into the national phase.

For detailed information about the procedural acts to be performed to enter the national phase before each designated Office, the applicable time limits and possible extensions of time or grace periods, and any other requirements, see the relevant Chapters of Volume II of the PCT Applicant's Guide. Information about the requirements for filing a demand for international preliminary examination is set out in Chapter IX of Volume I of the PCT Applicant's Guide.

GR and ES became bound by PCT Chapter II on 7 September 1996 and 6 September 1997, respectively, and may, therefore, be elected in a demand or a later election filed on or after 7 September 1996 and 6 September 1997, respectively, regardless of the filing date of the international application. (See second paragraph above.)

Note that only an applicant who is a national or resident of a PCT Contracting State which is bound by Chapter II has the right to file a demand for international preliminary examination.

CONFIRMATION OF PRECAUTIONARY DESIGNATIONS

This notification lists only specific designations made under Rule 4.9(a) in the request. It is important to check that these designations are correct. Errors in designations can be corrected where precautionary designations have been made under Rule 4.9(b). The applicant is hereby reminded that any precautionary designations may be confirmed according to Rule 4.9(c) before the expiration of 15 months from the priority date. If it is not confirmed, it will automatically be regarded as withdrawn by the applicant. There will be no reminder and no invitation. Confirmation of a designation consists of the filing of a notice specifying the designated State concerned (with an indication of the kind of protection or treatment desired) and the payment of the designation and confirmation fees. Confirmation must reach the receiving Office within the 15-month time limit.

REQUIREMENTS REGARDING PRIORITY DOCUMENTS

For applicants who have not yet complied with the requirements regarding priority documents, the following is recalled.

Where the priority of an earlier national, regional or international application is claimed, the applicant must submit a copy of the said earlier application, certified by the authority with which it was filed ("the priority document") to the receiving Office (which will transmit it to the International Bureau) or directly to the International Bureau, before the expiration of 16 months from the priority date, provided that any such priority document may still be submitted to the International Bureau before that date of international publication of the international application, in which case that document will be considered to have been received by the International Bureau on the last day of the 16-month time limit (Rule 17.1(a)).

Where the priority document is issued by the receiving Office, the applicant may, instead of submitting the priority document, request the receiving Office to prepare and transmit the priority document to the International Bureau. Such request must be made before the expiration of the 16-month time limit and may be subjected by the receiving Office to the payment of a fee (Rule 17.1(b)).

If the priority document concerned is not submitted to the International Bureau or if the request to the receiving Office to prepare and transmit the priority document has not been made (and the corresponding fee, if any, paid) within the applicable time limit indicated under the preceding paragraphs, any designated State may disregard the priority claim, provided that no designated Office may disregard the priority claim concerned before giving the applicant an opportunity to furnish the priority document within a time limit which is reasonable under the circumstances.

Where several priorities are claimed, the priority date to be considered for the purposes of computing the 16-month time limit is the filing date of the earliest application whose priority is claimed.

PATENT COOPERATION TREATY

OCT 2000

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION CONCERNING SUBMISSION OR TRANSMITTAL OF PRIORITY DOCUMENT

(PCT Administrative Instructions, Section 411)

To:

SAMMUT, Charles, P.
~~Limbach & Limbach~~ L.L.P.
2001 Ferry Building
San Francisco, CA 94111
ETATS-UNIS D'AMERIQUE

Date of mailing (day/month/year) 10 October 2000 (10.10.00)	
Applicant's or agent's file reference SONY-747PC	**IMPORTANT NOTIFICATION**
International application No. PCT/US00/11504	International filing date (day/month/year) 28 April 2000 (28.04.00)
International publication date (day/month/year) Not yet published	Priority date (day/month/year) 28 April 1999 (28.04.99)
Applicant SONY CORPORATION et al	

1. The applicant is hereby notified of the date of receipt (except where the letters "NR" appear in the right-hand column) by the International Bureau of the priority document(s) relating to the earlier application(s) indicated below. Unless otherwise indicated by an asterisk appearing next to a date of receipt, or by the letters "NR", in the right-hand column, the priority document concerned was submitted or transmitted to the International Bureau in compliance with Rule 17.1(a) or (b).

2. This updates and replaces any previously issued notification concerning submission or transmittal of priority documents.

3. An **asterisk(*)** appearing next to a date of receipt, in the right-hand column, denotes a priority document submitted or transmitted to the International Bureau but not in compliance with Rule 17.1(a) or (b). In such a case, **the attention of the applicant is directed** to Rule 17.1(c) which provides that no designated Office may disregard the priority claim concerned before giving the applicant an opportunity, upon entry into the national phase, to furnish the priority document within a time limit which is reasonable under the circumstances.

4. The **letters "NR"** appearing in the right-hand column denote a priority document which was not received by the International Bureau or which the applicant did not request the receiving Office to prepare and transmit to the International Bureau, as provided by Rule 17.1(a) or (b), respectively. In such a case, **the attention of the applicant is directed** to Rule 17.1(c) which provides that no designated Office may disregard the priority claim concerned before giving the applicant an opportunity, upon entry into the national phase, to furnish the priority document within a time limit which is reasonable under the circumstances.

Priority date	Priority application No.	Country or regional Office or PCT receiving Office	Date of receipt of priority document
28 Apri 1999 (28.04.99)	11/122734	JP	26 Sept 2000 (26.09.00)

The International Bureau of WIPO **34, chemin des Colombettes** **1211 Geneva 20, Switzerland** Facsimile No. (41-22) 740.14.35	Authorized officer Kanh Huynh-Khuong Telephone No. (41-22) 338.83.38

PATENT COOPERATION TREATY

PCT

From the INTERNATIONAL BUREAU

To:

SAMMUT, Charles, P.
Limbach & Limbach L.L.P.
2001 Ferry Building
San Francisco, CA 94111
ETATS-UNIS D'AMERIQUE

NOTIFICATION OF THE RECORDING OF A CHANGE

(PCT Rule 92bis.1 and Administrative Instructions, Section 422)

Date of mailing (day/month/year) 02 August 2000 (02.08.00)	
Applicant's or agent's file reference SONY-747PC	**IMPORTANT NOTIFICATION**
International application No. PCT/US00/11504	**International filing date** (day/month/year) 28 April 2000 (28.04.00)

1. The following indications appeared on record concerning:

☐ the applicant ☐ the inventor ☒ the agent ☐ the common representative

Name and Address	State of Nationality	State of Residence
SUMMUT, Charles, P.		
	Telephone No. 415 433 4150	
	Facsimile No. 415 433 8716	
	Teleprinter No.	

2. The International Bureau hereby notifies the applicant that the following change has been recorded concerning:

☐ the person ☒ the name ☐ the address ☐ the nationality ☐ the residence

Name and Address	State of Nationality	State of Residence
SAMMUT, Charles, P.		
	Telephone No. 415 433 4150	
	Facsimile No. 415 433 8716	
	Teleprinter No.	

3. Further observations, if necessary:
Please note that the agent's reference number has been changed from SONY-T0747 to SONY-747PC.

4. A copy of this notification has been sent to:

☒ the receiving Office
☒ the International Searching Authority
☐ the International Preliminary Examining Authority
☐ the designated Offices concerned
☐ the elected Offices concerned
☐ other:

The International Bureau of WIPO **34, chemin des Colombettes** **1211 Geneva 20, Switzerland** Facsimile No.: (41-22) 740.14.35	Authorized officer C. Carrié Christine Carrié Telephone No.: (41-22) 338.83.38

●TENT COOPERATION TRE●

From the INTERNATIONAL BUREAU

PCT

To:
SAMMUT, Charles, P.
Limbach & Limbach L.L.P.
2001 Ferry Building
San Francisco, CA 94111
ETATS-UNIS D'AMERIQUE

RECEIVED
NOV 13 2000
Limbach & Limbach

NOTICE INFORMING THE APPLICANT OF THE COMMUNICATION OF THE INTERNATIONAL APPLICATION TO THE DESIGNATED OFFICES

(PCT Rule 47.1(c), first sentence)

Date of mailing (day/month/year) 02 November 2000 (02.11.00)		
Applicant's or agent's file reference SONY-747PC	**IMPORTANT NOTICE**	
International application No. PCT/US00/11504	**International filing date** (day/month/year) 28 April 2000 (28.04.00)	**Priority date** (day/month/year) 28 April 1999 (28.04.99)
Applicant SONY CORPORATION et al		

1. Notice is hereby given that the International Bureau has communicated, as provided in Article 20, the international application to the following designated Offices on the date indicated above as the date of mailing of this Notice:
   US

   In accordance with Rule 47.1(c), third sentence, those Offices will accept the present Notice as conclusive evidence that the communication of the international application has duly taken place on the date of mailing indicated above and no copy of the international application is required to be furnished by the applicant to the designated Office(s).

2. The following designated Offices have waived the requirement for such a communication at this time:
   EP,JP

   The communication will be made to those Offices only upon their request. Furthermore, those Offices do not require the applicant to furnish a copy of the international application (Rule 49.1(a-bis)).

3. Enclosed with this Notice is a copy of the international application as published by the International Bureau on
   02 November 2000 (02.11.00) under No. WO 00/65847

REMINDER REGARDING CHAPTER II (Article 31(2)(a) and Rule 54.2)

If the applicant wishes to postpone entry into the national phase until 30 months (or later in some Offices) from the priority date, **a demand for international preliminary examination** must be filed with the competent International Preliminary Examining Authority before the expiration of 19 months from the priority date.

It is the applicant's sole responsibility to monitor the 19-month time limit.

Note that only an applicant who is a national or resident of a PCT Contracting State which is bound by Chapter II has the right to file a demand for international preliminary examination.

REMINDER REGARDING ENTRY INTO THE NATIONAL PHASE (Article 22 or 39(1))

If the applicant wishes to proceed with the international application in the **national phase**, he must, within 20 months or 30 months, or later in some Offices, perform the acts referred to therein before each designated or elected Office.

For further important information on the time limits and acts to be performed for entering the national phase, see the Annex to Form PCT/IB/301 (Notification of Receipt of Record Copy) and Volume II of the PCT Applicant's Guide.

The International Bureau of WIPO **34, chemin des Colombettes** **1211 Geneva 20, Switzerland**	Authorized officer J. Zahra
Facsimile No. (41-22) 740.14.35	Telephone No. (41-22) 338.83.38

PATENT COOPERATION TREATY

PCT

NOTIFICATION CONCERNING THE FILING OF AMENDMENTS OF THE CLAIMS

(PCT Administrative Instructions, Section 417)

From the INTERNATIONAL BUREAU

To:

SAMMUT, Charles, P.
Limbach & Limbach L.L.P.
2001 Ferry Building
San Francisco, CA 94111
ETATS-UNIS D'AMERIQUE

Date of mailing (day/month/year) 22 September 2000 (22.09.00)	
Applicant's or agent's file reference SONY-747PC	**IMPORTANT NOTIFICATION**
International application No. PCT/US00/11504	**International filing date** (day/month/year) 28 April 2000 (28.04.00)
Applicant SONY CORPORATION et al	

1. The applicant is hereby notified that amendments to the claims under Article 19 were received by the International Bureau on:

18 September 2000 (18.09.00)

2. This date is within the time limit under Rule 46.1.

Consequently, the international publication of the international application will contain the amended claims according to Rule 48.2(f), (h) and (i).

3. The applicant is reminded that the international application (description, claims and drawings) may be amended during the international preliminary examination under Chapter II, according to Article 34, and in any case, before each of the designated Offices, according to Article 28 and Rule 52, or before each of the elected Offices, according to Article 41 and Rule 78.

The International Bureau of WIPO **34, chemin des Colombettes** **1211 Geneva 20, Switzerland** Facsimile No.: (41-22) 740.14.35	Authorised officer Dominique DELMAS Telephone No.: (41-22) 338.83.38

EXPRESS MAIL LABEL NO. EL387347783US
Attorney Docket No. SONY-747US

PATENT COOPERATION TREATY

RECEIVED

AUG 10 2000

Limbach & Limbach

PCT

From the INTERNATIONAL SEARCHING AUTHORITY

To:
LIMBACH & LIMBACH L.L.P.
Attn. SUMMUT, Charles P.
2001 Ferry Building
SAN FRANCISCO, CALIFORNIA 94111
UNITED STATES OF AMERICA

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL SEARCH REPORT OR THE DECLARATION

(PCT Rule 44.1)

Date of mailing *(day/month/year)*	08/08/2000
Applicant's or agent's file reference ~~SONY-T0747~~ SONY-747PC	**FOR FURTHER ACTION** See paragraphs 1 and 4 below
International application No. PCT/US 00/11504	International filing date *(day/month/year)* 28/04/2000
Applicant SONY CORPORATION et al.	Due 10/8/00 cal'd [illegible]

1. [X] The applicant is hereby notified that the International Search Report has been established and is transmitted herewith.

Filing of amendments and statement under Article 19:
The applicant is entitled, if he so wishes, to amend the claims of the International Application (see Rule 46):

When? The time limit for filing such amendments is normally 2 months from the date of transmittal of the International Search Report; however, for more details, see the notes on the accompanying sheet.

Where? Directly to the International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland
Fascimile No.: (41-22) 740.14.35

For more detailed instructions, see the notes on the accompanying sheet.

2. [ ] The applicant is hereby notified that no International Search Report will be established and that the declaration under Article 17(2)(a) to that effect is transmitted herewith.

3. [ ] **With regard to the protest** against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:

[ ] the protest together with the decision thereon has been transmitted to the International Bureau together with the applicant's request to forward the texts of both the protest and the decision thereon to the designated Offices.

[ ] no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. **Further action(s):** The applicant is reminded of the following:

Shortly after **18 months** from the priority date, the international application will be published by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau as provided in Rules 90*bis*.1 and 90*bis*.3, respectively, before the completion of the technical preparations for international publication.

Within **19 months** from the priority date, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase until 30 months from the priority date (in some Offices even later).

Within **20 months** from the priority date, the applicant must perform the prescribed acts for entry into the national phase before all designated Offices which have not been elected in the demand or in a later election within 19 months from the priority date or could not be elected because they are not bound by Chapter II.

Name and mailing address of the International Searching Authority	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Shantisaroop Pherai

NOTES TO FORM PCT/ISA/220

These Notes are intended to give the basic instructions concerning the filing of amendments under article 19. The Notes are based on the requirements of the Patent Cooperation Treaty, the Regulations and the Administrative Instructions under that Treaty. In case of discrepancy between these Notes and those requirements, the latter are applicable. For more detailed information, see also the PCT Applicant's Guide, a publication of WIPO.

In these Notes, "Article", "Rule", and "Section" refer to the provisions of the PCT, the PCT Regulations and the PCT Administrative Instructions respectively.

INSTRUCTIONS CONCERNING AMENDMENTS UNDER ARTICLE 19

The applicant has, after having received the international search report, one opportunity to amend the claims of the international application. It should however be emphasized that, since all parts of the international application (claims, description and drawings) may be amended during the international preliminary examination procedure, there is usually no need to file amendments of the claims under Article 19 except where, e.g. the applicant wants the latter to be published for the purposes of provisional protection or has another reason for amending the claims before international pbulication. Furthermore, it should be emphasized that provisional protection is available in some States only.

What parts of the international application may be amended?

Under Article 19, only the claims may be amended.

During the international phase, the claims may also be amended (or further amended) under Article 34 before the International Preliminary Examining Authority. The description and drawings may only be amended under Article 34 before the International Examining Authority.

Upon entry into the national phase, all parts of the international application may be amended under Article 28 or, where applicable, Article 41.

When? Within 2 months from the date of transmittal of the international search report or 16 months from the priority date, whichever time limit expires later. It should be noted, however, that the amendments will be considered as having been received on time if they are received by the International Bureau after the expiration of the applicable time limit but before the completion of the technical preparations for international publication (Rule 46.1).

Where not to file the amendments?

The amendments may only be filed with the International Bureau and not with the receiving Office or the International Searching Authority (Rule 46.2).

Where a demand for international preliminary examination has been/is filed, see below.

How? Either by cancelling one or more entire claims, by adding one or more new claims or by amending the text of one or more of the claims as filed.

A replacement sheet must be submitted for each sheet of the claims which, on account of an amendment or amendments, differs from the sheet originally filed.

All the claims appearing on a replacement sheet must be numbered in Arabic numerals. Where a claim is cancelled, no renumbering of the other claims is required. In all cases where claims are renumbered, they must be renumbered consecutively (Administrative Instructions, Section 205(b)).

The amendments must be made in the language in which the international application is to be published.

What documents must/may accompany the amendments?

Letter (Section 205(b)):

The amendments must be submitted with a letter.

The letter will not be published with the international application and the amended claims. It should not be confused with the "Statement under Article 19(1)" (see below, under "Statement under Article 19(1)").

The letter must be in English or French, at the choice of the applicant. However, if the language of the international application is English, the letter must be in English; if the language of the international application is French, the letter must be in French.

The letter must indicate the differences between the claims as filed and the claims as amended. It must, in particular, indicate, in connection with each claim appearing in the international application (it being understood that identical indications concerning several claims may be grouped),whether

(i) the claim is unchanged;

(ii) the claim is cancelled;

(iii) the claim is new;

(iv) the claim replaces one or more claims as filed;

(v) the claim is the result of the division of a claim as filed.

The following examples illustrate the manner in which amendments must be explained in the accompanying letter:

1. [Where originally there were 48 claims and after amendment of some claims there are 51]: "Claims 1 to 29, 31, 32, 34, 35, 37 to 48 replaced by amended claims bearing the same numbers; claims 30, 33 and 36 unchanged; new claims 49 to 51 added."

2. [Where originally there were 15 claims and after amendment of all claims there are 11]: "Claims 1 to 15 replaced by amended claims 1 to 11."

3. [Where originally there were 14 claims and the amendments consist in cancelling some claims and in adding new claims]:
"Claims 1 to 6 and 14 unchanged; claims 7 to 13 cancelled; new claims 15, 16 and 17 added." or
"Claims 7 to 13 cancelled; new claims 15, 16 and 17 added; all other claims unchanged."

4. [Where various kinds of amendments are made]:
"Claims 1-10 unchanged; claims 11 to 13, 18 and 19 cancelled; claims 14, 15 and 16 replaced by amended claim 14; claim 17 subdivided into amended claims 15, 16 and 17; new claims 20 and 21 added."

"Statement under article 19(1)" (Rule 46.4)

The amendments may be accompanied by a statement explaining the amendments and indicating any impact that such amendments might have on the description and the drawings (which cannot be amended under Article 19(1)).

The statement will be published with the international application and the amended claims.

It must be in the language in which the international appplication is to be published.

It must be brief, not exceeding 500 words if in English or if translated into English.

It should not be confused with and does not replace the letter indicating the differences between the claims as filed and as amended. It must be filed on a separate sheet and must be identified as such by a heading, preferably by using the words "Statement under Article 19(1)."

It may not contain any disparaging comments on the international search report or the relevance of citations contained in that report. Reference to citations, relevant to a given claim, contained in the international search report may be made only in connection with an amendment of that claim.

Consequence if a demand for international preliminary examination has already been filed

If, at the time of filing any amendments under Article 19, a demand for international preliminary examination has already been submitted, the applicant must preferably, at the same time of filing the amendments with the International Bureau, also file a copy of such amendments with the International Preliminary Examining Authority (see Rule 62.2(a), first sentence).

Consequence with regard to translation of the international application for entry into the national phase

The applicant's attention is drawn to the fact that, where upon entry into the national phase, a translation of the claims as amended under Article 19 may have to be furnished to the designated/elected Offices, instead of, or in addition to, the translation of the claims as filed.

For further details on the requirements of each designated/elected Office, see Volume II of the PCT Applicant's Guide.

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference	FOR FURTHER ACTION	see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.
SONY-T0747		
International application No. PCT/US 00/11504	International filing date (*day/month/year*) 28/04/2000	(Earliest) Priority Date (*day/month/year*) 28/04/1999
Applicant SONY CORPORATION et al.		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 3 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

   a. With regard to the **language**, the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

   [ ] the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

   b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing :

   [ ] contained in the international application in written form.
   [ ] filed together with the international application in computer readable form.
   [ ] furnished subsequently to this Authority in written form.
   [ ] furnished subsequently to this Authority in computer readble form.
   [ ] the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
   [ ] the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

2. [ ] **Certain claims were found unsearchable** (See Box I).
3. [ ] **Unity of invention is lacking** (see Box II).

4. With regard to the **title,**

   [ ] the text is approved as submitted by the applicant.
   [X] the text has been established by this Authority to read as follows:

   METHODS AND APPARATUS FOR COLOR DEVICE CHARACTERIZATION

5. With regard to the **abstract,**

   [X] the text is approved as submitted by the applicant.
   [ ] the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is Figure No. 5

   [X] as suggested by the applicant.
   [ ] because the applicant failed to suggest a figure.
   [ ] because this figure better characterizes the invention.
   [ ] None of the figures.

EXPRESS MAIL LABEL NO. EL387347783US
Attorney Docket No. SONY-747US

PCT

REQUEST

The undersigned requests that the present international application be processed according to the Patent Cooperation Treaty.

For receiving Office use only
International Application No.
International Filing Date
Name of receiving Office and "PCT International Application"

Applicant's or agent's file reference *(if desired) (12 characters maximum)*	SONY-747PC

Box No. I TITLE OF INVENTION

METHODS AND APPARATUS FOR COLOR DEVICE CHARACTERIZATION, IMAGE COLOR CORRECTION, METHODS OF TRANSMISSION AND/OR RECORDING OF COLOR IMAGE DATA AND RECORDING MEDIUM THEREFC

Box No. II APPLICANT

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*	[ ] This person is also inventor.
SONY CORPORATION 7-35, Kitashinagawa 6-chome Shinagawa-ku, Tokyo 141-0001 JAPAN	Telephone No. (03) 5448-2617 Facsimile No. (03) 5448-3063 Teleprinter No.
State *(that is, country)* of nationality: JP	State *(that is, country)* of residence: JP

This person is applicant for the purposes of: [ ] all designated States [X] all designated States except the United States of America [ ] the United States of America only [ ] the States indicated in the Supplemental Box

Box No. III FURTHER APPLICANT(S) AND/OR (FURTHER) INVENTOR(S)

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*	This person is:
NISHIO, Kenichi c/o Sony Corporation 7-35, Kitashinagawa 6-chome Shinagawa-ku, Tokyo 141-0001 JAPAN	[ ] applicant only [X] applicant and inventor [ ] inventor only *(If this check-box is marked, do not fill in below.)*
State *(that is, country)* of nationality: JP	State *(that is, country)* of residence: JP

This person is applicant for the purposes of: [ ] all designated States [ ] all designated States except the United States of America [X] the United States of America only [ ] the States indicated in the Supplemental Box

[X] Further applicants and/or (further) inventors are indicated on a continuation sheet.

Box No. IV AGENT OR COMMON REPRESENTATIVE; OR ADDRESS FOR CORRESPONDENCE

The person identified below is hereby/has been appointed to act on behalf of the applicant(s) before the competent International Authorities as: [X] agent [ ] common representative

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*	Telephone No. (415) 433-4150
SAMMUT, Charles P. LIMBACH & LIMBACH L.L.P. 2001 Ferry Building San Francisco, CA 94111 United States of America	Facsimile No. (415) 433-8716 Teleprinter No.

[ ] **Address for correspondence:** Mark this check-box where no agent or common representative is/has been appointed and the space above is used instead to indicate a special address to which correspondence should be sent.

Continuation of Box No. III FURTHER APPLICANTS AND/OR (FURTHER) INVENTOR(S)

If none of the following sub-boxes is used, this sheet is not to be included in the request.

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

MIZUTANI, Eiji
c/o Sony Corporation
7-35, Kitashinagawa 6-chome
Shinagawa-ku, Tokyo 141-0001
Japan

This person is:

- ☐ applicant only
- ☒ applicant and inventor
- ☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality: US/JP

State *(that is, country)* of residence: US

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☒ the United States of America only ☐ the States indicated in the Supplemental Box

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

This person is:

- ☐ applicant only
- ☐ applicant and inventor
- ☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality:

State *(that is, country)* of residence:

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☐ the United States of America only ☐ the States indicated in the Supplemental Box

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

This person is:

- ☐ applicant only
- ☐ applicant and inventor
- ☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality:

State *(that is, country)* of residence:

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☐ the United States of America only ☐ the States indicated in the Supplemental Box

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

This person is:

- ☐ applicant only
- ☐ applicant and inventor
- ☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality:

State *(that is, country)* of residence:

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☐ the United States of America only ☐ the States indicated in the Supplemental Box

☐ Further applicants and/or (further) inventors are indicated on another continuation sheet.

Box No.V DESIGNATION OF STATES

The following designations are hereby made under Rule 4.9(a) *(mark the applicable check-boxes; at least one must be marked)*:

Regional Patent

☐ **AP ARIPO Patent: GH** Ghana, **GM** Gambia, **KE** Kenya, **LS** Lesotho, **MW** Malawi, **SD** Sudan, **SL** Sierra Leone, **SZ** Swaziland, **TZ** United Republic of Tanzania, **UG** Uganda, **ZW** Zimbabwe, and any other State which is a Contracting State of the Harare Protocol and of the PCT

☐ **EA Eurasian Patent: AM** Armenia, **AZ** Azerbaijan, **BY** Belarus, **KG** Kyrgyzstan, **KZ** Kazakhstan, **MD** Republic of Moldova, **RU** Russian Federation, **TJ** Tajikistan, **TM** Turkmenistan, and any other State which is a Contracting State of the Eurasian Patent Convention and of the PCT

☒ **EP European Patent**: **AT** Austria, **BE** Belgium, **CH and LI** Switzerland and Liechtenstein, **CY** Cyprus, **DE** Germany, **DK** Denmark, **ES** Spain, **FI** Finland, **FR** France, **GB** United Kingdom, **GR** Greece, **IE** Ireland, **IT** Italy, **LU** Luxembourg, **MC** Monaco, **NL** Netherlands, **PT** Portugal, **SE** Sweden, and any other State which is a Contracting State of the European Patent Convention and of the PCT

☐ **OA OAPI Patent**: **BF** Burkina Faso, **BJ** Benin, **CF** Central African Republic, **CG** Congo, **CI** Côte d'Ivoire, **CM** Cameroon, **GA** Gabon, **GN** Guinea, **GW** Guinea-Bissau, **ML** Mali, **MR** Mauritania, **NE** Niger, **SN** Senegal, **TD** Chad, **TG** Togo, and any other State which is a member State of OAPI and a Contracting State of the PCT *(if other kind of protection or treatment desired, specify on dotted line)* ....

National Patent *(if other kind of protection or treatment desired, specify on dotted line)*:

☐ **AE** United Arab Emirates
☐ **AL** Albania ....
☐ **AM** Armenia ....
☐ **AT** Austria ....
☐ **AU** Australia ....
☐ **AZ** Azerbaijan
☐ **BA** Bosnia and Herzegovina ....
☐ **BB** Barbados
☐ **BG** Bulgaria ....
☐ **BR** Brazil ....
☐ **BY** Belarus ....
☐ **CA** Canada
☐ **CH and LI** Switzerland and Liechtenstein
☐ **CN** China ....
☐ **CR** Costa Rica ....
☐ **CU** Cuba ....
☐ **CZ** Czech Republic ....
☐ **DE** Germany ....
☐ **DK** Denmark ....
☐ **DM** Dominica
☐ **EE** Estonia ....
☐ **ES** Spain ....
☐ **FI** Finland ....
☐ **GB** United Kingdom
☐ **GD** Grenada
☐ **GE** Georgia ....
☐ **GH** Ghana ....
☐ **GM** Gambia
☐ **HR** Croatia ....
☐ **HU** Hungary ....
☐ **ID** Indonesia
☐ **IL** Israel ....
☐ **IN** India ....
☐ **IS** Iceland
☒ **JP** Japan ....
☐ **KE** Kenya ....
☐ **KG** Kyrgyzstan ....
☐ **KP** Democratic People's Republic of Korea ....
☐ **KR** Republic of Korea ....
☐ **KZ** Kazakhstan ....
☐ **LC** Saint Lucia
☐ **LK** Sri Lanka
☐ **LR** Liberia
☐ **LS** Lesotho ....
☐ **LT** Lithuania
☐ **LU** Luxembourg
☐ **LV** Latvia
☐ **MA** Morocco ....
☐ **MD** Republic of Moldova ....
☐ **MG** Madagascar ....
☐ **MK** The former Yugoslav Republic of Macedonia ....
☐ **MN** Mongolia
☐ **MW** Malawi ....
☐ **MX** Mexico ....
☐ **NO** Norway
☐ **NZ** New Zealand ....
☐ **PL** Poland ....
☐ **PT** Portugal ....
☐ **RO** Romania
☐ **RU** Russian Federation ....
☐ **SD** Sudan
☐ **SE** Sweden
☐ **SG** Singapore
☐ **SI** Slovenia ....
☐ **SK** Slovakia ....
☐ **SL** Sierra Leone ....
☐ **TJ** Tajikistan ....
☐ **TM** Turkmenistan ....
☐ **TR** Turkey ....
☐ **TT** Trinidad and Tobago ....
☐ **TZ** United Republic of Tanzania
☐ **UA** Ukraine ....
☐ **UG** Uganda ....
☒ **US** United States of America ....
☐ **UZ** Uzbekistan ....
☐ **VN** Viet Nam ....
☐ **YU** Yugoslavia ....
☐ **ZA** South Africa ....
☐ **ZW** Zimbabwe ....

Check-boxes reserved for designating States which have become party to the PCT after issuance of this sheet:

☐ ....
☐ ....

Precautionary Designation Statement: In addition to the designations made above, the applicant also makes under Rule 4.9(b) all other designations which would be permitted under the PCT except any designation(s) indicated in the Supplemental Box as being excluded from the scope of this statement. The applicant declares that those additional designations are subject to confirmation and that any designation which is not confirmed before the expiration of 15 months from the priority date is to be regarded as withdrawn by the applicant at the expiration of that time limit. *(Confirmation (including fees) must reach the receiving Office within the 15-month time*

Supplemental Box *If the Supplemental Box is not used, this sheet need not be included in the request.*

1. If, in any of the Boxes, ***the space is insufficient*** *to furnish all the information: in such case, write "Continuation of Box No. ..." [indicate the number of the Box] and furnish the information in the same manner as required according to the captions of the Box in which the space was insufficient, in particular:*

(i) ***if more than two persons are involved as applicants and/or inventors*** *and no "continuation sheet" is available: in such case, write "Continuation of Box No. III" and indicate for each additional person the same type of information as required in Box No. III. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below;*

(ii) if, in Box No. II or in any of the sub-boxes of Box No. III, the indication ***"the States indicated in the Supplemental Box"*** *is checked: in such case, write "Continuation of Box No. II" or "Continuation of Box No. III" or "Continuation of Boxes No. II and No. III" (as the case may be), indicate the name of the applicant(s) involved and, next to (each) such name, the State(s) (and/or, where applicable, ARIPO, Eurasian, European or OAPI patent) for the purposes of which the named person is applicant;*

(iii) if, in Box No. II or in any of the sub-boxes of Box No. III, ***the inventor or the inventor/applicant is not inventor for the purposes of all designated States or for the purposes of the United States of America:*** *in such case, write "Continuation of Box No. II" or "Continuation of Box No. III" or "Continuation of Boxes No. II and No. III" (as the case may be), indicate the name of the inventor(s) and, next to (each) such name, the State(s) (and/or, where applicable, ARIPO, Eurasian, European or OAPI patent) for the purposes of which the named person is inventor;*

(iv) if, in addition to the agent(s) indicated in Box IV, there are ***further agents****: in such case, write "Continuation of Box No. IV" and indicate for each further agent the same type of information as required in Box No. IV;*

(v) if, in Box No. V, the name of any State (or OAPI) is accompanied by the indication ***"patent of addition,"*** *or* ***"certificate of addition,"*** *or if, in Box No. V, the name of the United States of America is accompanied by an indication* ***"continuation"*** *or* ***"continuation-in-part"****: in such case, write "Continuation of Box No. V" and the name of each State involved (or OAPI), and after the name of each such State (or OAPI), the number of the parent title or parent application and the date of grant of the parent title or filing of the parent application;*

(vi) if, in Box No. VI, there are ***more than three earlier applications whose priority is claimed****: in such case, write "Continuation of Box No. VI" and indicate for each additional earlier application the same type of information as required in Box No. VI;*

(vii) if, in Box No. VI, ***the earlier application is an ARIPO application****: in such case, write "Continuation of Box No. VI", specify the number of the item corresponding to that earlier application and indicate at least one country party to the Paris Convention for the Protection of Industrial Property or one Member of the World Trade Organization for which that earlier application was filed.*

2. If, with regard to the ***precautionary designation statement*** *contained in Box No. V, the applicant wishes to exclude any State(s) from the scope of that statement: in such case, write "Designation(s) excluded from precautionary designation statement" and indicate the name or two-letter code of each State so excluded.*

3. If the applicant claims, in respect of any designated Office, the benefits of provisions of the national law concerning ***non-prejudicial disclosures or exceptions to lack of novelty****: in such case, write "Statement concerning non-prejudical disclosures or exceptions to lack of novelty" and furnish that statement below.*

Continuation from Box IV.:

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Box No. VI PRIORITY CLAIM

☐ Further priority claims are indicated in the Supplemental Box.

Filing date of earlier application (day/month/year)	Number of earlier application	Where earlier application is: national application: country	regional application:* regional Office	international application: receiving Office
item (1) 28 April 1999 (28.04.99)	P11-122734	JP		
item (2)				
item (3)				

☐ The receiving Office is requested to prepare and transmit to the International Bureau a certified copy of the earlier application(s) *(only if the earlier application was filed with the Office which for the purposes of the present international application is the receiving Office)* identified above as item(s):

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Box No. VII INTERNATIONAL SEARCHING AUTHORITY

Choice of International Searching Authority (ISA) *(if two or more International Searching Authorities are competent to carry out the international search, indicate the Authority chosen; the two-letter code may be used):*

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Box No. VIII CHECK LIST: LANGUAGE OF FILING

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claims	:	21
abstract	:	1
drawings	:	13
sequence listing part of description	:	
Total number of sheets	:	76

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Figure of the drawings which should accompany the abstract: 5

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Charles P. Sammut

Attorneys for Applicant

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FEE CALCULATION SHEET

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Applicant
SONY CORPORATION

CALCULATION OF PRESCRIBED FEES

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first 30 sheets	427.00	b1
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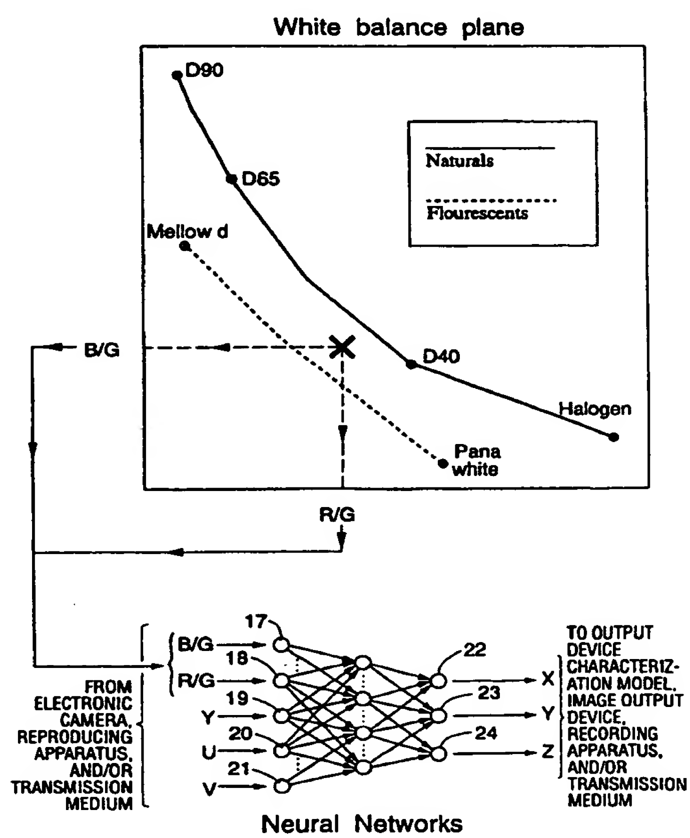
(57) Abstract

Methods and apparatus for color correction of color image data obtained by an electronic camera determine a correction to data representative of the color image based upon an estimated illuminant using a neural network, multilayer perceptron models and/or coactive neuro–fuzzy inference system models, and apply the correction to the data representative of the color image. Data representative of the color corrected data may be recorded or transmitted. A method of recording image data obtained by an electronic camera captures a color image, generates data representative of the image, estimates an illuminant for the captured color image, generates data representative of the estimated illuminant and records the data representative of the image with the data representative of the estimated illuminant. A method of transmitting image data obtained by an electronic camera captures a color image, generates data representative of the image, estimates an illuminant for the captured color image, generates data representative of the estimated illuminant and transmits the data representative of the image with the data representative of the estimated illuminant.



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METHODS AND APPARATUS FOR COLOR DEVICE CHARACTERIZATION

Background of the Invention

1. Field of the Invention

The present invention relates to color correction of images, and in particular relates to methods and apparatus for color device characterization, correcting color of a color image obtained by an electronic camera, transmission of color corrected data and a recording medium having recorded thereon a color corrected data of a color image.

2. Description of the Related Art

There are known in the art two approaches for performing color correction for an image captured by an electronic color camera. A first approach is to directly convert the camera's output data into the same color space as camera's output color space with improved color accuracy. For instance, when the camera's output space is YUV (defined below), the color correction model's input and output spaces are YUV, but with higher color accuracy at the output YUV. Hereinafter, this approach will be referred to as "device specific color correction." "YUV" is a color representation which is typically used in connection with video transmission. "Y" represents luminance, "U" represents a component of colors corresponding approximately to blue minus yellow, while "V" represents component of colors corresponding approximately to red minus cyan. Other color representations include "RGB" (red, green blue) and "YCC" where YCC indicates any color space consisting of one luminance factor and two chrominance factors. The above-described YUV is one example of a YCC color representation. YIQ,

is another example of a YCC color representation, where "I" is a component of colors corresponding approximately to yellow-ish red minus light blue, while "Q" is a component of colors corresponding approximately to violet minus green-ish yellow. YCbCr (luminance, chrominance-blue, chrominance-red is yet another example of a YCC color representation.

A second approach for color correction is divided into two steps. First, the camera's output color space is once converted into a colorimetric space (XYZ or L*a*b*), the space which is specified by CIE (International Illumination Committee, originally published in the French language). A colorimetric color space attempts to describe color of natural objects perceived by human eyes. Color data described in a colorimetric space corresponds to the original color of the images taken by an electronic color camera. In a second step, the color data converted into such a colorimetric space is then converted into an output device's (computer monitor or printer) specific color space, where the entire image path can provide colorimetrically correct color reproduction. This two-step concept is incorporated in the ICC (International Color Committee) color profile format, which is commonly used in computer image processing where relatively high accuracy is required in color reproduction. In the context of the color correction based on ICC's concept, the intermediate colorimetric space is often referred to as a "device independent color space." Therefore, this color correction approach is referred to as "device independent color correction."

To perform the above-described device-independent color correction, one should attempt to determine an inverse function of a camera's color transformation. This step is called "color device characterization" for an electronic camera, and such characterization is employed to correct color of images obtained by the electronic camera. The conventional practice for determining the inverse

function of an electronic camera's color transformation is to apply a method widely used for determining an inverse function of image scanners' color transformation. This approach has been considered reasonable, because most color cameras have signal processing similar to that of image scanners.

Figure 1 shows the signal-processing diagram that is used in both image scanners and most electronic color cameras. In Figure 1, input data of image sensor 104 of camera 100 is assumed to be in colorimetric space XYZ, which is provided to inputs 101, 102 and 103, respectively. The output space of image sensor 104 is RGB, while the camera's output space is YCC. Camera output is provided at outputs 110, 111, and 112, corresponding to Y, C and C, respectively.

A simple reverse-model, shown in Figure 2, can be used to approximate the inverse function of the color transformation formed by the image sensor camera 100 shown in Figure 1. In Figure 2, each block should perform inverse conversion of corresponding blocks in Figure 1. The pairs of corresponding blocks are 104-124, 151-161, 152-162, 153-163 and 109-122. Specifically, matrices 104 and 109 should be inverse matrices of 124 and 122 respectively. Tone reproduction curves ("TRCs"), which are usually implemented by one-dimensional lookup tables ("1D-LUTs") 151, 152, and 153, should be inverse functions of 1D-LUTs 161, 162 and 163, respectively. Since this color correction model consists of matrices and TRCs, it is called a "TRC-matrix model."

As shown in Figures 1 and 2, the color transformation of image sensor 104 is linearly approximated by a 3x3 matrix 124. According to color science for electronic cameras, an image sensor's spectral analysis characteristics ideally should be a linear combinations of color matching functions xyz specified by CIE, that is, a set of spectral functions which represent human eye's color

sensitivity. Since all color cameras are designed to target these ideal characteristics, in many cases a 3x3 matrix can well approximate an image sensor used in electronic cameras, thereby providing a reasonably accurate inverse function of the camera's color transformation. This TRC-matrix model approach, however, cannot perform an accurate color correction under some circumstances.

Approximation accuracy

When an image sensor's color transformation cannot be well approximated by a 3x3 matrix in the TRC-matrix model (124 in Figure 2), color correction cannot be accurate. This situation can likely occur in many entry-level electronic cameras. This is also the case when the camera's signal processing does not match the configuration shown in Figure 1, such that the configuration of Figure 2 can no longer be a reverse model of the camera. For instance, Figure 3 is a block diagram which illustrates signal processing typically used in a CMYG (Cyan, Magenta, Yellow, and Green, also referred to as "complementary color") electronic color camera. At first glance, Figure 2 cannot work as a reverse model for the signal processing of Figure 3. In addition, it is not easy to construct a simple reverse model for the signal processing performed by the system of Figure 3, due to structural complexity of a CMYG camera's signal processing.

Illuminant dependency

In the case of an electronic camera, whether it be a still camera or one intended to record a succession of still or moving images, there is a somewhat unique problem, more specifically, that of illuminant dependency of color transformation. While an image scanner captures images using one fixed built-in illuminant all the time, an electronic camera captures images under a variety of

illuminants, for example, outdoors at dawn, mid-day or late afternoon, indoors with fluorescent, incandescent or other types of artificial lighting, a combination of artificial lighting, or even a combination of natural (outdoor) and artificial lighting. In an electronic camera, there is a mechanism to estimate the illuminant at the time of image capturing, wherein the camera's gain settings at R, G, and B channels are adjusted according to the on-camera illuminant estimation, so that the final output image has R=G=B with respect to a white object. This operation is called "white balancing," and the gain adjustment is placed between image sensor 104 and 1D-LUTs 105 in Figure 1, although it is not shown in the diagram. Usually, color transformation of a camera changes depending on the setting of white balancing. In other words, an electronic camera has illuminant dependency in its color transformation. It means color distortion or error caused by an electronic camera changes depending on illuminant. Therefore, for highly accurate color correction, it is necessary to prepare for inverse functions of the camera's color transformation under all possible illuminants, which is impractical. One existing solution for this problem is to prepare for a set of inverse functions (likely in a form of ICC color profile, using either a TRC-matrix model or a three-dimensional lookup table) of color transformation under several representative illuminants. A user then has to manually select from the set of preset inverse functions, considering which inverse function is the best fit to the illumination under which the user actually captured the image. This not only is a burden for the user, but also can result in inaccurate color correction if the user's selection is inappropriate. Furthermore, inaccurate correction can also occur when the actual illumination used for the image capture falls between the preset inverse functions. This is a limitation of the lookup-table based (TRC-matrix) method. Another limitation of

the look-up table based method is its inability to accurately correct color under multi-illuminant conditions. An alternative to the TRC-matrix method is the three dimensional lookup table ("3D-LUT"). Although such a 3D-LUT is more accurate than the TRC-matrix, the size of the correction model is huge, and it is, as with the TRC-matrix method, incapable of accurately correcting color under multi-illuminant conditions. Thus, it would be desirable to provide a method and apparatus for accurately correcting the color of images taken by an electronic camera under arbitrary illuminants.

Summary of the Invention

It is an object of the invention to provide a method and apparatus for correcting the color of images obtained by an electronic camera under a variety of illuminants.

It is also an object of the invention to provide a method and apparatus for characterizing a color device.

It is an additional object of the invention to provide a method and apparatus for correcting the color of images obtained by an electronic camera under a combination of illuminants.

It is yet another object of the invention to provide a recording medium having recorded thereon data representative of color corrected color images.

It is yet an additional object of the invention to provide a method of transmitting data representative of color corrected color images.

It is a feature of the invention to correct color of a color image by utilizing a neural network as a function approximator to overcome the limitations of the look-up table method in determining a correction to data representative of the color image.

It is a feature of the invention to correct color of a color image by utilizing a multilayer perceptron ("MLP"), a form of neural

network, to determine a correction to data representative of the color image.

It is yet another feature of the invention to correct color of a color image by utilizing a coactive neuro-fuzzy inference system ("CANFIS") model to determine a correction to data representative of the color image.

It is yet a further feature of the invention to perform an automatic color correction of a color image obtained by an electronic camera in the case of multi-illuminant conditions.

It is yet another feature of the invention to convert image data into XYZ space, thereby providing better accuracy in white point and in color under sophisticated off-camera illumination estimation.

It is yet an additional feature of the invention to easily realize color constancy by modifying or replacing a training data set.

It is an advantage of the invention to a higher color correction accuracy of images obtained by an electronic camera than is generally possible with a conventional TRC-matrix.

It is a further advantage of the invention to allow electronic camera users to concentrate on composition instead of spending time on color correction during a photo shoot, but also at the time of displaying and/or printing a photo.

According to one aspect of the invention, there is provided a method of correcting color of a color image obtained by an electronic camera, comprising the steps of determining, using a neural network, a correction to data representative of the color image based upon an estimated illuminant of the color image; and applying the correction to the data representative of the color image, wherein the illuminant comprises multiple sources of illumination.

According to another aspect of the invention, there is provided a method of correcting color of a color image obtained by an electronic camera, comprising the steps of determining, using a

multilayer perceptron model, a correction to data representative of the color image based upon an estimated illuminant of the color image; and applying the correction to the data representative of the color image, wherein the illuminant comprises multiple sources of illumination.

According to a further aspect of the invention, there is provided a method of correcting color of a color image obtained by an electronic camera, comprising the steps of determining, using a coactive neuro-fuzzy inference system model, a correction to data representative of the color image based upon an estimated illuminant of the color image; and applying the correction to the data representative of the color image, wherein the illuminant comprises multiple sources of illumination.

According to yet another aspect of the invention, there is provided an apparatus for correcting color of a color image obtained by an electronic camera, comprising a neural network for determining a correction to data representative of the color image based upon an estimated illuminant of the color image and for applying the correction to the data representative of the color image, wherein the illuminant comprises multiple sources of illumination.

According to yet a further aspect of the invention, there is provided an apparatus for correcting color of a color image obtained by an electronic camera, comprising a multilayer perceptron model for determining a correction to data representative of the color image based upon an estimated illuminant of the color image, and for applying the correction to the data representative of the color image, wherein the illuminant comprises multiple sources of illumination.

According to another aspect of the invention, there is provided an apparatus for correcting color of a color image obtained by an electronic camera, comprising: a coactive neuro-fuzzy inference system model for determining a correction to data

representative of the color image based upon an estimated illuminant of the color image, and for applying the correction to the data representative of the color image, wherein the illuminant comprises multiple sources of illumination.

According to a further aspect of the invention, there is provided a recording medium having recorded thereon color corrected data of a color image obtained by an electronic camera, the recording medium being prepared by the steps of determining, using a neural network, a correction to data representative of the color image based upon an estimated illuminant of the color image; applying the correction to the data representative of the color image, wherein the illuminant comprises multiple sources of illumination; and recording on the recording medium data representative of the corrected data.

According to yet another aspect of the invention, there is provided a recording medium having recorded thereon color corrected data of a color image obtained by an electronic camera, the recording medium being prepared by the steps of determining, using a multilayer perceptron model, a correction to data representative of the color image based upon an estimated illuminant of the color image; applying the correction to the data representative of the color image, wherein the illuminant comprises multiple sources of illumination; and recording on the recording medium data representative of the corrected data.

According to yet another aspect of the present invention, there is provided a recording medium having recorded thereon color corrected data of a color image obtained by an electronic camera, the recording medium being prepared by the steps of determining, using a coactive neuro-fuzzy inference system model, a correction to data representative of the color image based upon an estimated illuminant of the color image; applying the correction to the data

representative of the color image, wherein the illuminant comprises multiple sources of illumination; and recording on the recording medium data representative of the corrected data.

According to an aspect of the invention, there is provided a method of transmitting color corrected data of a color image obtained by an electronic camera, comprising the steps of determining, using a neural network, a correction to data representative of the color image based upon an estimated illuminant of the color image; applying the correction to the data representative of the color image, wherein the illuminant comprises multiple sources of illumination; and transmitting data representative of the corrected data.

According to another aspect of the invention, there is provided a method of transmitting color corrected data of a color image obtained by an electronic camera, comprising the steps of: determining, using a multilayer perceptron model, a correction to data representative of the color image based upon an estimated illuminant of the color image; applying the correction to the data representative of the color image, wherein the illuminant comprises multiple sources of illumination; and transmitting data representative of the corrected data.

According to a further aspect of the invention, there is provided a method of transmitting color corrected data of a color image obtained by an electronic camera, comprising the steps of: determining, using a coactive neuro-fuzzy inference system model, a correction to data representative of the color image based upon an estimated illuminant of the color image; applying the correction to the data representative of the color image, wherein the illuminant comprises multiple sources of illumination; and transmitting data representative of the corrected data.

According to an aspect of the invention, there is provided a method of recording image data obtained by an electronic camera, comprising the steps of: capturing a color image and generating data representative of the image; estimating an illuminant for the captured color image and generating data representative of the estimated illuminant; and recording the data representative of the image with the data representative of the estimated illuminant.

According to a further aspect of the invention, there is a provided a method of transmitting image data obtained by an electronic camera, comprising the steps of: capturing a color image and generating data representative of the image; estimating an illuminant for the captured color image and generating data representative of the estimated illuminant; and transmitting the data representative of the image with the data representative of the estimated illuminant.

These and other objects, features and advantages will become apparent when considered with reference to the following description and the accompanying drawings.

Brief Description of the Drawings

Figure 1 is a block diagram of a signal processor used in both image scanners and electronic color cameras.

Figure 2 is a reverse signal processor for use in connection with the signal processor of Figure 1.

Figure 3 is a block diagram of a signal processor typically used in a complementary color electronic camera.

Figure 4A is a block diagram of an embodiment of a color correcting apparatus of the present invention in which a neural network is utilized to generate an inverse function (or mapping) of an electronic camera's color transformation.

Figure 4B is a diagram of an embodiment of a color correcting apparatus of the present invention in which multilayer perceptrons are utilized to generate an inverse function (or mapping) of an electronic camera's color transformation.

Figure 5 is a diagram of an embodiment of a color correcting apparatus of the present invention in which single multilayer perceptron are utilized to generate a color corrected output space converted image.

Figure 6A is an illustration of a dogleg trajectory having a piecewise linear curve determined by the Cauchy step and the Newton step, connecting θ_{now} and θ_{Newton} by the route through θ_{Cauchy}.

Figure 6B is an illustration of a dogleg step which leads to θ_{next}, where the dogleg step is a piecewise linear approximation to a restricted Levenberg-Marquardt step within the trust region.

Figure 7 is a graph which illustrates a comparison in color difference under a D65-illuminant between a single multilayer perceptron approach and a conventional look-up-table based (TRC-matrix) approach.

Figure 8 is a diagram of the architecture of a CANFIS neuro-fuzzy model of the present invention.

Figure 9 is a graph which illustrates representative illuminants and related "natural" and "flourescent" curves.

Figure 10 is a graph which illustrates fuzzy partitioning by four bell-shaped membership functions on a transformed white balance plane.

Figure 11 illustrates a data distribution on original coordinates of a white balance plane.

Figure 12 illustrates a data distribution on normalized coordinates of the white balance plane.

Figure 13 illustrates a neural network transformed distribution on transformed coordinates of the white balance plane.

Detailed Description of the Preferred Embodiments

To solve the problems described above, a neural network (e.g., a MLP) or a CANFIS neuro-fuzzy model is utilized. Although the invention is applicable to both "device specific" and "device independent" approaches, the embodiments disclosed herein are described herein in relation to device independent color correction. It is to be understood that a MLP is just one type of well known neural network. Furthermore, where a neural network is specified in herein, a MLP or other type of neural network may be utilized.

A single-illuminant color correction using an MLP.

As discussed above, when a color correction using a TRC-matrix model (Figure 1) cannot be accurate even under one fixed known illuminant, the cause is likely to be non-ideality, nonlinearity or structural complexity in the electronic camera. A neural network as shown in Figure 4A or a MLP model as shown in Figure 4B can be used instead of the TRC-matrix model to improve the correction accuracy. In Figure 4A any neural network may be utilized, for example, the MLP of Figure 4b. With the neural network (e.g., MLP) model, the correction can be based on one fixed illuminant, thus hereinafter referred to as "single-illuminant" color correction. A color correction model using a neural network (e.g., MLP) had been used only for imaging devices such as printers, whose color transformation is highly nonlinear and whose white point (corresponding to the color of illumination in case of an electronic camera) is considered fixed.

A Y input 1, a C input 2 and a C input 3 provide image data to neural network 4 as shown in Figure 4A. Image data is provided from an electronic camera. Alternatively, image data may be provided to inputs 1, 2 and 3 from a reproducing apparatus and/or a transmission medium. In the latter instances, since illumination

information necessary for color correction is only available from the electronic camera, such illumination information should be recorded and/or transmitted with the image data, or should otherwise be provided to the neural network 4. In the case of transmission or recording of image data from an electronic camera, many image data formats include unused fields or spaces for use by image printers. Such fields or spaces are typically available to record the date of a photo shoot, a camera model designation or a camera manufacturer designation. Therefore, one or more unused field or space may be allocated to illumination information, such that the image data is recorded and/or transmitted together with the illumination information, but before any color correction has been applied to the image data.

The neural network 4 provides an X output 5, a Y output 6 and a Z output 7 in the colorimetric space XYZ. As shown in Figure 4B, the MLP has three input nodes, Y, U and V, designated by reference numerals 11, 12 and 13, respectively, for camera's output values (RGB or YCC). The MLP also has three output nodes X, Y and Z, designated by reference numerals 14, 15 and 16, respectively. Output nodes X, Y and Z provide either colorimetric values (XYZ or L*a*b*) for device-independent color correction, or target output values in RGB or YCC for device-specific color correction. These colorimetric or color-corrected output values may be provided to image output devices, such as printers or display monitors, via the output device's characterization model. The values may also be directly provided to image output devices. Alternatively, these values, encoded and/or compressed versions thereof, may be recorded by a recording apparatus onto a recording medium such as a magnetic disc, an optical disc, a magneto-optical disc, or a sold state memory, or may be transmitted through a

transmission medium such as the Internet, telephone lines, dedicated lines, radio frequency or an optical medium.

For optimizing an MLP's parameters, a set of input-output samples, called a "training" data set, is prepared that includes representative color samples, pairs of inputs YUV and desired outputs XYZ. Then a given task is formulated as a nonlinear least squares problem, in which, the objective is to optimize an MLP's parameters by minimizing a squared error measure between the desired outputs and the model's outputs.

The objective function E(.), the squared error measure, can be expressed by residual vectors $r(\theta)$ as:

$$E(\theta) = (1/2)r^T(\theta)r(\theta)$$

The parameter optimization is carried out iteratively with the aim of eventually making the model reproduce the desired outputs. This iterative process is referred to as "training" (or "learning") in the neural network literature.

Besides the "training" data set, an MLP's approximation capacity is often measured by using a different data set, called a "checking" data set, which is not employed for parameter adjustment. One important advantage of neural networks, and in particular, those of an MLP, are the results obtained for input data outside of the training data set.

In the posed "device-independent" color correction problem, the MLP is trained to form a mapping from a camera's response signals (e.g., RGB or YCC) to colorimetric values (e.g., XYZ or L*a*b*). In the "device-specific" color correction problem, the MLP's desired mapping is from error-corrupted camera's response signals (RGB or YCC) to their associated corrected RGB or YCC signals. In any event, those input-output samples are collected by using the standard Macbeth ColorChecker or Munsell color patches,which are evenly distributed in the entire color space.

Note that if the data are collected under a certain single illuminant, then the task becomes the so-called single-illuminant problem, which is ubiquitous in color correction for images captured by image scanners.

Multi-illuminant color correction using an MLP

Referring now to Figure 5, an MLP model is used to achieve an automatic color correction for images captured by an electronic camera under arbitrary illuminant (at the time of image capture). The MLP model is trained so that it automatically adjusts its mapping, an inverse function of the camera in a case of device-independent correction, depending on the illuminant used at the time of image capture. This is hereinafter referred to as "multi-illuminant" color correction. Since it is difficult to exactly know what illuminant was used at the time of image capture, the model instead takes advantage of the electronic camera's on-camera illumination estimation data (or white balancing data), R/G and B/G values for instance, where R, G, and B are measured signal values for illumination color, as illustrated in the upper portion of Figure 5. In Figure 5 "Pana white" refers to a trademark for a "white" flourescent bulb sold in Japan by Matsushita Electric Industrial Co. Ltd. of Osaka, Japan. "Mellow d" refers to a trademark which identifies a "daylight" type of flourescent bulb sold in Japan by Toshiba Lighting & Technology Co. of Tokyo, Japan. It is to be understood that Figure 13 can be used in place of the upper portion of Figure 5 (White balance plane)

The MLP used for the multi-illuminant color correction should have additional nodes to input the illumination information. For instance, two additional input nodes can be used because illumination chromaticity can be described by a set of two values. Consequently, the MLP model for this task has five input nodes B/G,

R/G, Y, U and V, designated by reference numbers 17, 18, 19, 20 and 21, respectively, and three output nodes X, Y and Z, designated by reference numerals 22, 23 and 24, respectively, as shown in Figure 5. The outputs X, Y and Z, or transformed, normalized, encoded and/or compressed versions thereof, may be recorded by a recording apparatus onto a recording medium such as magnetic disc, an optical disc, a magneto-optical disc, or a solid state memory or may be transmitted through a transmission medium such as the Internet, telephone lines, dedicated lines, radio frequency or an optical medium.

In accordance with one embodiment of the invention, the following steps are taken to train a multi-illuminant color correction model:

(1) Measure an electronic camera's output values and colorimetric values (for device-independent correction) of a set of color samples under several representative illuminants. The total size of training data set is therefore N*M, where N is the number of color samples and M is the number of representative illuminants under consideration.

(2) For each illuminant, measure gain data of the RGB channels as applied to balance white, or instead, measure signal values of RGB channels for illuminant color.

(3) Convert the measured three values onto a set of two chromaticity values, for instance, R/G and B/G. The data may be further processed to better characterize the illuminant information, as described below with respect to a method for constructing fuzzy membership functions for the CANFIS neuro-fuzzy model.

(4) An MLP is trained using the data set (1), as described above. At the same time, the data set (3), that is, the illuminant information under which data (1) is measured, are provided to the input nodes 17 (B/G) and 18 (R/G).

After the above described steps have been completed, the MLP model outputs the original scene's colorimetric values by having camera's output values and the illuminant information at its input. The camera's illuminant dependency of color transformation is automatically compensated by referring to the illumination information. When the illuminant actually used at the time or times of image capture does not coincide to any of the representative illuminants used for the MLP training, the MLP automatically approximates the inverse function of the camera's color transformation between illuminants.

Method for training MLP models

Due to the nonlinearity of MLPs, an efficient iterative method is desirable for solving the NN nonlinear least squares problem posed in above section. Numerical tests have revealed that a dogleg trust-region implementation of the Levenberg-Marquardt-type algorithm is suitable for the problem to be solved. In further detail, dogleg methods produce an efficient piecewise linear approximation of the restricted Levenberg-Marquardt step within the trust region.

Figures 6A and 6B illustrate how the dogleg step approximates the trust region step over a two dimensional subspace spanned by the Cauchy step and the Newton (or Gauss-Newton) step. The crosspoint between the piecewise linear dogleg trajectory (highlighted in Figure 6A) and the trust-region boundary yields one of

the next three steps:

1. Restricted Cauchy step:

$$S_{RC} \stackrel{def}{=} -R_{now}\frac{g_{now}}{\|g_{now}\|}$$

when the trust radius R_{now} is smaller than the length of the Cauchy step S_{Cauchy}, which is given by

$$S_{Cauchy} \stackrel{def}{=} -\frac{g_{now}^T g_{now}}{g_{now}^T H_{now} g_{now}} g_{now}$$

where g and H denote the gradient vector and the Hessian matrix, respectively.

2. Newton step:

$$S_{Newton} \stackrel{def}{=} -H_{now}^{-1} g_{now}$$

when the trust radius is larger than or equal to the length of the Newton step.

3. Dogleg step:

$$S_{Dogleg} \stackrel{def}{=} S_{Cauchy} + h_{now}(S_{Newton} - S_{Cauchy})$$

when the trust radius is in between the Cauchy step and the Newton step. One of those steps is employed at each iteration for optimizing the model by the iterative scheme:

$$\theta_{next} = \theta_{now} + \eta d\ ,$$

where d is a direction vector and η is some positive step size regulating to what extent to proceed in that direction. The parameter h in Figure 6A can be determined in a straightforward calculation:

$$h_{now} = \frac{R_{now}^2 - S_{Cauchy}^T S_{Cauchy}}{(S_{Newton} - S_{Cauchy})^2 S_{Cauchy} + \sqrt{p_{now}}}$$

where

$$\begin{aligned} p_{now} = {} & (S_{Newton} - S_{Cauchy})^T (S_{Newton} - S_{Cauchy}) R_{now}^2 \\ & + (S_{Newton}^T S_{Cauchy})^2 - (S_{Newton}^T S_{Newton})(S_{Cauchy}^T S_{Cauchy}) \end{aligned}$$

The power of the dogleg trust-region strategy resides in ease for a smooth transition between the steepest descent method (global convergence property) and Newton's method (fast local convergence property), making the algorithm very robust. For instance, when a next step is not satisfactory, the dogleg algorithm shortens the step length and deflects it towards the steepest descent direction simultaneously and efficiently based on a simple trust-region control.

Table 1 below compares the convergence speed of three representative nonlinear optimization algorithms in a single-illuminant (D65-illuminant) problem:

	25 training data	51 checking data	Stopped epoch
1D-lookup table with a 3 x 3 matrix transformation	0.015900	0.025576	N/A
MLP with 7 hidden units by steepest descent-based pattern-by-pattern learning	0.005792	0.016862	1,000,000 (10,818.61 sec.)
MLP with 10 hidden units by steepest descent-based pattern-by-pattern learning	0.004608	0.015991	1,000,000
MLP with 7 hidden units by Polak-Ribiere conjugate gradient batch learning	0.005797	0.018310	2,400 (114.65 sec.)
MLP with 10 hidden units by Polak-Ribiere conjugate gradient batch learning	0.004519	0.016344	2,000
MLP with 7 hidden units by a dogleg-driven Levenberg-Marquardt learning	0.00552	0.017947	44 (8.54 sec.)

TABLE 1

The performance comparison is in root mean squared error of scaled XYZ values between the TRC-matrix oriented model and the MLP models with three representative learning algorithms. Note in the last column "Stopped epoch" that the required execution time (in seconds) is shown parenthesized only the for (3 x 7 x 3) MLP models with seven hidden units. From Table 1 it is clear that for a single-illuminant color correction problem, the use of the dogleg driven Levenberg-Marquardt converges faster than the other tested learning techniques indicated in Table 1. Such performance comparison is further discussed in *Color device characterization of*

electronic cameras by solving adaptive networks nonlinear least squares problems, Eiji Mizutani (a co-inventor of the present application), Kenichi Nishio (the other co-inventor of the present application), Naoya Katoh and Michael Blasgen, 8th IEEE International Conference on Fuzzy Systems (FUZZ-IEEE'99), Seoul, Korea, August 22-25, 1999, which paper and the figures therein are hereby incorporated by reference. Furthermore, the dogleg trust-region algorithms are further discussed in *Computing Powell's Dogleg Steps for Solving Adaptive Networks Nonlinear Least-Squares Problems*, Eiji Mizutani (a co-inventor of the present application), 8th International Fuzzy Systems Association World Congress (IFSA'99), Hsinchu, Taiwan, August 17-20, 1999, and in *Powell's dogleg trust-region steps with the quasi-Newton augmented Hessian for neural nonlinear least-squares learning*, Eiji Mizutani (a co-inventor of the present application), The IEEE International Conference on Neural Networks, Washington D.C., July 10-16, 1999, both of which papers and the figures therein are hereby incorporated by reference.

Referring now to Figure 7, such Figure illustrates a comparison in color difference under a D65 illuminant between a single MLP approach and a conventional look-up table based (TRC-matrix) approach. Note that all 25 color differences (for 24 Macbeth color checkers and a "perfect-black"color sample) must be smaller than 10. Figure 7 clearly illustrates an MLP based method effectively reduces the color difference down below an upper-limit threshold value (set equal to 10) for all 25 color samples under the D65 illuminant, whereas a conventional look-up-table based (TRC matrix) method failed to do so.

Multi-illuminant color correction using a CANFIS neuro-fuzzy model

A CANFIS neuro-fuzzy model is specially designed to perform automatic "multi-illuminant" color correction based on problem-specific knowledge, which is represented by a collection of fuzzy if-then rules: In particular, "IF-part" is expressed by fuzzy membership functions (MFs) and "THEN-part" is constructed by local-expert MLPs. This is the so-called "CANFIS with neural rules" model.

In particular, four fuzzy rules are specified in accordance with fuzzy-partitioning on the two-dimensional transformed white balance plane, as explained below in relation to a method for constructing fuzzy membership functions. The resulting CANFIS neuro-fuzzy model consists of four fuzzy MFs (two for each axis) and four associated local-expert MLPs, as illustrated in Figure 8. The input vector is split into two vectors for IF-part (MFs) and THEN-part (MLPs):

1. Two inputs of on-camera illumination information fed into fuzzy MFs;
2. Three inputs of camera's output signals (e.g., YUV) fed into local-expert MLPs.

The CANFIS model computes a weighted sum of the outputs of local-expert MLPs as the final output vector A (e.g., X, Y, Z color signals) by

$$A = \sum_{i=1}^{4} g_i O_i$$

where g_i and O_i are the i-th firing strength and the i-th MLP's output vector, respectively. Each firing strength, given by the product of IF-part MF outputs, represents the extent to which the associated THEN-part MLP affects the final output. In this context, a set of IF-

part MFs plays a role as an integrating unit that combines the outputs of fired THEN-part MLPs.

Usually, the integrating unit is composed of bell-shaped differentiable fuzzy MFs and their neighboring MFs are set up to have sufficient overlap. Hence, all of the associated local-expert MLPs function complementarily to generate the final output in the equation for the value of A. On the other hand, if the integrating unit is constructed by non-overlapped rectangular MFs resulting in a switching unit, then only a single local-expert MLP contributes to the final output. Only one of the g_i values becomes a "unit" with all of the others being "zero." Such a single non-zero g_i is associated with the i-th "fired" local expert MLP. In other words, local expert MLPs function competitively rather than complementarily. Stated differently, the CANFIS concept basically resides in the synergism among fuzzy MFs and local-expert MLPs, ruling out such an extreme switching case.

The CANFIS model has an advantage in that without increasing the number of fuzzy MFs (so that fuzzy rules can be held to meaningful limits), the model can increase learning capacity just by applying an appropriate architectural or algorithmic modification solely to the local-expert MLPs. For instance, such modification can simply adjust the number of MLP hidden nodes/layers. It should be noted that the CANFIS model can be viewed as a local-tuning RBFN (Radial Basis Function Network) model when the hidden layers of THEN-part MLPs are eliminated. Hence, the CANFIS model can be regarded as a generalized local-tuning neural network.

Its disadvantages might be slower learning due to architectural complexity and a requirement of larger training data, compared with a single MLP model. Therefore, if the task has a small limited number of training data, then an MLP model might be a better choice. Experimental results obtained with the CANFIS model are

presented below in relation to a method for training a CANFIS neuro-fuzzy model for multi-illuminant color correction.

The CANFIS with linear rules model is equivalent to the well-known Takagi-Sugeno (also called "TSK" or "Sugeno-type") fuzzy inference model. In the field of control engineering, where a quick response is important, this TSK model is by far the most commonly used fuzzy system. The quickness comes from a computational advantage since implementation of linear rules is much simpler than implementation of nonlinear rules.

CANFIS modeling and CANFIS with linear rules are explained in detail at pages 369-400 and 572-592, of the text *Neuro-Fuzzy and Soft Computing, A Computational Approach to Learning and Machine Intelligence*, by Jyh-Shing Roger Jang, Chuen-Tsai Sun and Eiji Mizutani (co-inventor of the present application), Prentice Hall, Upper Saddle River, New Jersey 07458, 1997, third printing, which pages and the figures therein are hereby incorporated by reference.

Method for constructing fuzzy membership functions for multi-illuminant color correction using the CANFIS neuro-fuzzy model described above.

Fuzzy Partitioning

In the CANFIS neuro-fuzzy model, fuzzy membership functions (MFs) partition the MF-input space into several local-expert's territories. Hence, data that come close to the center of a certain local-expert's area may not affect very much to the parameter-updatings of the other local experts. This local-tuning mechanism can make "local experts" learn locally optimal mainly for the vicinity of their own local regions.

For the multiple-illuminant problem as illustrated in Figure 9, data in the halogen illuminant region should not make a significant impact on a local-expert MLP in the D90-illuminant region, which is

at the other end of the "natural-illuminant" curve on the white balance plane. Those two extreme regions must be somehow distinguished by an appropriate partitioning. Fuzzy MFs plays an important role in partitioning the illuminant territories on the white balance plane in a "fuzzy" (but not "crisp") fashion, as illustrated in Figure 10. In Figure 10, two representative illuminants, halogen and D65, are chosen to determine the initial center positions of the two MFs on the X-axis, which corresponds to the "natural-illuminant" curve. This implies that the location along that curve is selected as an important feature in the task. The two linguistic labels "A1" and "A2" on the X-axis in Figure 10 signify the respective "Halogen" and "D65" where:

The value/degree of A1-MF shows how close the illuminant is to the "Halogen" illuminant; and

The value/degree of A2-MF shows how close the illuminant is to the "D65" illuminant.

Clearly, only one feature may not be sufficient for describing each illuminant's region appropriately. Another important feature is the distinction between the "natural" and the "fluorescent" illuminants. Therefore, two corresponding MFs (B1 for "fluorescent" and B2 for "natural") are constructed on the Y-axis to represent closeness to the fluorescent and natural illuminants, where:

The B1-MF value shows how close to the "fluorescent" illuminant-curve; and

The B2-MF value shows how close to the "natural" illuminant-curve.

In this way, each of mixed illuminants along the "mixtures" curve in Figure 9 can be characterized by the degree of membership to the "natural" or "fluorescent" illuminant, as would be the case where an illuminant consisted of a 40 % natural illuminant and a 60 % fluorescent illuminant. In Figure 9, "Lupica ace" refers to a

trademark which identifies a "neutral" type of flourescent bulb sold in Japan by Mitsubishi Electric Co. of Tokyo, Japan. Since the X and Y axes in Figures 9 and 10 are not the same, a certain "nonlinear" coordinate transformation is needed. Such coordinate transformation is described below.

Nonlinear Coordinate Transformation on the White-Balance Plane

Figure 11 shows an actual data distribution of experimental data sets on the original R/G-B/G white balance plane. To conform Figure 11 to Figure 10, it is necessary to introduce an appropriate coordinate transformation. First, a simple linear-scaling is applied, resulting in Figure 12. Then a neural network nonlinear coordinate transformation is applied, yielding Figure 13, where Figure 13 has Cartesian coordinates that match those of Figure 10, although many other nonlinear transformations are possible.

The importance of nonlinear coordinate transformation cannot be overemphasized because it allows simple "grid" partitionings. There are several advantages over "scatter" partitionings as are typically formed by a radial basis function network ("RBFN"). RBFNs are explained in detail at pages 238-246 and 369-400, and in particular, at Figure 13.3 on page 373 of said text *Neuro-Fuzzy and Soft Computing, A Computational Approach to Learning and Machine Intelligence*, which pages and the figures therein are hereby incorporated by reference.

In further detail, nonlinear coordinate transformation provides the following advantages:

1. Linguistic interpretability can be kept sufficiently high to match our intuitive understandings; and
2. The required number of (basis) functions can be reduced.

Advantage #1 insinuates that clear linguistic labels may not be readily put on each MF in the case of scatter or tree partitionings. Advantage #2 indicates, for instance, that in order to form nine local regions on the X-Y plane, the RBFN needs nine basis functions, whereas the CANFIS model requires six MFs (three MFs for each axis). Accordingly, the total number of function parameters differs. Further detail regarding partitioning is taught at pages 86 and 87 of said *Neuro-Fuzzy and Soft Computing, A Computational Approach to Learning and Machine Intelligence*, which pages and the figures therein are hereby incorporated by reference.

Method for training a CANFIS neuro-fuzzy model for multi-illuminant color correction.

Many nonlinear optimization algorithms can be employed for training the CANFIS neuro-fuzzy model described above in relation to a multi-illuminant color correcting using a CANFIS neuro-fuzzy model. The model consists of two major parameterized constituents:

(1) "fuzzy MFs (IF-part);"" and

(2) "local-expert MLPs (THEN-part),"

as illustrated in Figure 8. There are many possibilities in applying optimization algorithms to update the parameters of these two constituents, for example:

(Method A) Apply the same optimization algorithm to both IF-part MFs and THEN-part MLPs; or

(Method B) Apply different optimization algorithms to IF-part MFs and THEN-part MLPs.

These methods can be implemented in either a system-wise or a component-wise manner. For system-wise training, all components, MFs and MLPs, of the CANFIS neuro-fuzzy model are trained simultaneously as a system, whose final output is computed by the

above equation for the value of A as set forth above. For component-wise training, each MF or MLP is tuned/trained independently, and then all the components are put together to form the CANFIS neuro-fuzzy model, whose final output is computed by the above equation for the value of A as set forth above.

To be more specific by referring to Figure 8, in the component-wise manner, each local expert MLP is usually trained to produce the desired final output vector A (i.e., X, Y, Z) as the output vector O_i. On the other hand, in the system-wise training manner, the final output vector A (as set forth above) is attempted to be made to match the desired triplet X, Y and Z, but each local expert MLP's output vector O_i may not be necessarily close to it; that is, each output vector O_i may not be interpretable. In Figure 8, the three output nodes of each local expert MLP are tagged by X, Y and Z, merely for the purpose of showing which node is related to which signal.

Furthermore, there are three different parameter-updating modes, depending on treatment of training data:

(1) online pattern-by-pattern updating mode;

(2) block-by-block updating mode; and

(3) batch updating mode.

Therefore, there are many possible applications of any optimization algorithms to the CANFIS model. It is worth noting, however, that regardless of whether Method A or Method B is utilized, the component-wise training is questionable in obtaining highly accurate results because local-expert MLPs' outputs are optimized independently of the firing strengths of fuzzy MFs in spite of the dependence expressed in the above equation for the value of A as set forth above. Thus, the other system-wise training is of much greater practical importance, especially when the CANFIS model

needs to produce very accurate input/output mappings, as required in color correction of color images.

In general, an important observation can be made in neuro-fuzzy systems that the parameters of MLPs are far from optimal values, compared with those of MFs, because the initial parameters of fuzzy MFs are determined based on problem-specific knowledge, whereas the initial parameters of local-expert MLPs are randomly initialized. Therefore, application of different optimization algorithms to MFs and MLPs (i.e., implementation of Method B) is possible; in particular, application of a faster algorithm to MLPs and a slower algorithm to MFs. A typical demonstration in this spirit is the hybrid-learning of ANFIS (i.e., single-output CANFIS with linear rules model), a combination of fast "linear" least squares and a slow steepest descent-type method, although it is restricted to "linear" consequent fuzzy systems. Such hybrid-learning is detailed at pages 219-220 and 222-223 of said text *Neuro-Fuzzy and Soft Computing, A Computational Approach to Learning and Machine Intelligence*, supra, which pages and the figures therein are hereby incorporated by reference.

Method A in the system-wise training manner can be considered in the same spirit for the CANFIS with neural rules model; for instance, by applying the steepest descent-type method to MFs in the "batch" mode and it to MLPs in the "online pattern-by-pattern" mode. This strategy can be improved in conjunction with a simple heuristic rule; for instance:

Rule: Fix the parameters of fuzzy MFs at an early stage of training phase.

Table 2 shows four representative results obtained with MLP and CANFIS models, when the checking error was minimized or at the preset limit iteration of 2,000,000. The column "# of Para." refers to the number of parameters and "RMSE" refers to the root

mean squared error. The columns labelled "# of bad samples" are most important, denoting the number of color samples whose color differences were greater than the upper-limit threshold value (set equal to 10). All of the four models were trained by using the widely-employed steepest descent-type method in the online pattern-by-pattern updating mode.

Exp. #	Structure	# of Para.	Stopped epoch	Training XYZ-RMSE	Average color diff.	# of bad samples	Checking XYZ-RMSE	Average color diff.	# of bad samples
1	5 x 22 x 3 MLP	201	148,500	0.006176	3.09685	13	0.005781	2.88622	52
2	5 x 45 x 3 MLP	408	347,500	0.005044	2.57207	11	0.004601	2.29206	39
3	CANFIS (HU=10)	304	2,000,000	0.006356	2.85213	7	0.006688	2.80347	35
4	CANFIS (HU=10)	304	1,771,000	0.005476	2.52347	0	0.005542	2.44866	0

TABLE 2

The results in Experiment #4 were obtained by using the following heuristic rule:

Rule: Start updating the parameters of fuzzy MFs after 500,000 epochs.

Selection of output color space

In the present disclosure, XYZ space is mainly used as an output color space of color correction models. As described earlier herein, the output color space can also be L*a*b* or XnYnZn (normalized XYZ space) for device-independent color correction. For device-specific color correction, it can be any color space that the color imaging device subject to the color correction outputs, or can even be a color space arbitrarily defined according to a user's specific requirement. The change of output color space can be achieved by simply replacing the target output data for color correction model's training data set.

As discussed above in relation to Illuminant dependency, an electronic camera's output values are white-balanced to keep R=G=B at illuminant color. XnYnZn and L*a*b* color spaces also have a similar operation in their definition, wherein tri-stimulus values are normalized by values for illuminant color. Such a color space can be denoted as a normalized color space. This operation represents the human eye's chromatic adaptation.

As shown in Figure 1, an electronic camera's output values are based on gamma-corrected RGB. Similar operations are found in the definition of L*a*b* color space, and such a color spaces can be considered to be a nonlinear color space. The nonlinear mapping is for a correlation with lightness (a measure for human's luminance perception), to better describe perceived color by human eyes rather than the physical property of color.

A non-normalized linear color space, such as XYZ, can provide an advantage when used as a multi-illuminant color correction model's output color space. An image captured by an electronic camera may have incorrect white point, due to incorrect estimation of illumination automatically made on the camera. For such a case, white point correction can be readily made off the camera after capturing the image, if the color correction model's output space is XYZ. If the output space is a nonlinear color space, white point correction is more complicated because the output data has to be once brought into a linear space to perform the white point correction.

It can be assumed that an electronic camera's color transformation is a function of its white-balance setting, as described above in relation to Illuminant dependency. No matter how correct or incorrect the on-camera estimation of illumination is, the camera's color transformation can be uniquely determined by referring to the camera's white-balance information, R/G and B/G for instance. Therefore, XYZ values that output from a multi-illuminant color correction model can well describe the original color's physical property, even if the input image's white point is incorrect. When a user determines that the white point is incorrect in an image taken by an electronic camera, the user can first output image data in XYZ from the multi-illuminant color correction model, then can re-estimate the image's illumination using a sophisticated method, which is too computationally expensive to be performed on-camera. The method can provide accuracy not only in white point, but also in color distributed around the re-balanced white point, because the re-balancing is applied to image data in corrected color space. A non-normalized linear color space can also be a space formed at an image sensor's output (raw image data).

Color constancy

It is known that many users prefer an electronic camera that reproduces color as if images were captured under one fixed standard illuminant such as D50 (specified by CIE, 5000K daylight), no matter what illuminant is actually used at the image capturing. This is referred to as "color constancy" color reproduction. By appropriately modifying the training data set of the above described multi-illuminant color correction model using either an MLP or a CANFIS neuro-fuzzy architecture, the above described "color-constancy" color correction is easily accomplished.

It is to be understood that although an MLP is described as one example of a neural network which is applicable to the present invention, other types of neural networks such as a radial basis function network ("RBFN") or a modular neural network may also be utilized.

It is to be further understood that each embodiment of the present invention may be implemented as software to be run on a computer or may be implemented as a function of image processing software run on a computer. In such an instance, image data files may be opened by the software, and any embodiment of the present invention may be applied to image data, such as a JPEG, GIF or BMP format file to allow color correction to be applied to such image data.

It is additionally to be understood that the methods and apparatus of the present invention may be applied to characterize a component in a color imaging device, such as an image sensor in an electronic camera. It is to be further understood that such characterization may be employed to correct for undesired qualities of such image sensor.

Although only certain embodiments have been described in detail, those having ordinary skill in the art will certainly understand

that many modifications are possible without departing from the teachings hereof. All such modifications are intended to be encompassed within the following claims.

We claim:

1. A method of correcting color of a color image obtained by an electronic camera, comprising the steps of:

determining, using a neural network, a correction to data representative of the color image based upon an estimated illuminant of the color image; and

applying the correction to the data representative of the color image, wherein the illuminant comprises multiple sources of illumination.

2. The method of claim 1, wherein the electronic camera captures at least one still image..

3. The method of claim 1, wherein the electronic camera captures a succession of moving images.

4. A method of correcting color of a color image obtained by an electronic camera, comprising the steps of:

determining, using a multilayer perceptron model, a correction to data representative of the color image based upon an estimated illuminant of the color image; and

applying the correction to the data representative of the color image, wherein the illuminant comprises multiple sources of illumination.

5. The method of claim 4, wherein the electronic camera captures at least one still image.

6. The method of claim 4, wherein the electronic camera captures a succession of moving images.

7. The method of claim 4, wherein the multilayer perceptron model is trained based upon a dogleg trust region implementation of a Levenberg-Marquardt type algorithm.

8. The method of claim 4, further comprising the step of:
outputting an output color space of the color corrected image as a space not normalized with chromaticity coordinates the sources of illumination.

9. The method of claim 4, further comprising the step of:
using training data of each neural network as a colorimetric value under a standard source of illumination.

10. A method of correcting color of a color image obtained by an electronic camera, comprising the steps of:
determining, using a coactive neuro-fuzzy inference system model, a correction to data representative of the color image based upon an estimated illuminant of the color image; and
applying the correction to the data representative of the color image, wherein the illuminant comprises multiple sources of illumination.

11. The method of claim 10, wherein the electronic camera captures at least one still image.

12. The method of claim 10, wherein the electronic camera captures a succession of moving images.

13. The method of claim 10, wherein an integrating unit comprised of fuzzy membership functions computes a weighted sum of outputs of local expert multilayer perceptrons based upon an on-camera estimation of illumination at a time of color image capture.

14. The method of claim 13, further comprising the step of:
constructing fuzzy membership functions by applying a neural network nonlinear coordinate transformation to a white balance plane in order to characterize estimated illumination for the coactive neuro-fuzzy inference system model.

15. The method of claim 10, further comprising the step of:
training the coactive neuro-fuzzy inference system model by constructing fuzzy membership functions generated by applying a neural network nonlinear coordinate transformation to a white balance plane in order to characterize estimated illumination for the coactive neuro-fuzzy inference system model.

16. The method of claim 13, further comprising the step of:
training the coactive neuro-fuzzy inference system model by constructing fuzzy membership functions generated by applying a neural network nonlinear coordinate transformation to a white balance plane in order to characterize estimated illumination for the coactive neuro-fuzzy inference system model, wherein all parameters of fuzzy membership functions and local expert multilayer perceptrons are updated simultaneously.

17. The method of claim 13, further comprising the step of:

training the coactive neuro-fuzzy inference system model by constructing fuzzy membership functions generated by applying a neural network nonlinear coordinate transformation to a white balance plane in order to characterize estimated illumination for the coactive neuro-fuzzy inference system model, wherein all parameters of fuzzy membership functions and local expert multilayer perceptrons are updated simultaneously in conjunction with a heuristic parameter updating rule.

18. The method of claim 13, 14, 15, 16 or 17, wherein at least two of the fuzzy membership functions overlap.

19. A method of correcting color of a color image obtained by an electronic camera, comprising the steps of:

determining, using a coactive neuro-fuzzy inference system with a switching unit, a correction to data representative of the color image based upon an estimated illuminant of the color image.

20. The method of claim 10, further comprising the steps of:

finding a color conversion inverse map using separate neural networks associated with respective representative sources of illumination; and

outputting an output color space of the color corrected image as a space not normalized with chromaticity coordinates the sources of illumination.

21. The method of claim 10, further comprising the steps of:

finding a color conversion inverse map using neural networks associated with respective representative sources of illumination; and

outputting an output color space of the color corrected image as a space not normalized with chromaticity coordinates the sources of illumination.

22. The method of claim 10, further comprising the steps of:

finding a color conversion inverse map using separate neural networks associated with respective representative sources of illumination; and

using training data of each neural network as a colorimetric value under a standard source of illumination.

23. The method of claim 10, further comprising the steps of:

finding a color conversion inverse map using neural networks associated with respective representative sources of illumination; and

using training data of each neural network as a colorimetric value under a standard source of illumination.

24. An apparatus for correcting color of a color image obtained by an electronic camera, comprising:

a neural network for determining a correction to data representative of the color image based upon an estimated illuminant of the color image and for applying the correction to

the data representative of the color image, wherein the illuminant comprises multiple sources of illumination.

25. The apparatus of claim 24, wherein the electronic camera captures at least one still image.

26. The apparatus of claim 24, wherein the electronic camera captures a succession of moving images.

27. An apparatus for correcting color of a color image obtained by an electronic camera, comprising:

a multilayer perceptron model for determining a correction to data representative of the color image based upon an estimated illuminant of the color image, and for applying the correction to the data representative of the color image, wherein the illuminant comprises multiple sources of illumination.

28. The apparatus of claim 27, wherein the electronic camera captures at least one still image.

29. The apparatus of claim 27, wherein the electronic camera captures a succession of moving images.

30. The apparatus of claim 27, wherein the multilayer perceptron model is trained based upon a dogleg trust region implementation of a Levenberg-Marquardt type algorithm.

31. The apparatus of claim 27, wherein the multilayer perceptron model outputs an output color space of the color corrected image as a space not normalized with chromaticity coordinates the sources of illumination.

32. The apparatus of claim 27, wherein the multilayer perceptron model uses training data of each neural network as a colorimetric value under a standard source of illumination.

33. An apparatus for correcting color of a color image obtained by an electronic camera, comprising:

a coactive neuro-fuzzy inference system model for determining a correction to data representative of the color image based upon an estimated illuminant of the color image, and for applying the correction to the data representative of the color image, wherein the illuminant comprises multiple sources of illumination.

34. The apparatus of claim 33, wherein the electronic camera captures at least one still image.

35. The apparatus of claim 33, wherein the electronic camera captures a succession of moving images.

36. The apparatus of claim 33, wherein an integrating unit comprised of fuzzy membership functions computes a weighted sum of outputs of local expert multilayer perceptrons based upon an on-camera estimation of illumination at a time of color image capture.

37. The apparatus of claim 36, wherein fuzzy membership functions are constructed by applying a neural network nonlinear coordinate transformation to a white balance plane in order to characterize estimated illumination for the coactive neuro-fuzzy inference system model.

38. The apparatus of claim 33, wherein the coactive neuro-fuzzy inference system model is trained by constructing fuzzy membership functions generated by applying a neural network nonlinear coordinate transformation to a white balance plane in order to characterize estimated illumination for the coactive neuro-fuzzy inference system model.

39. The apparatus of claim 36, wherein the coactive neuro-fuzzy inference system model is trained by constructing fuzzy membership functions generated by applying a neural network nonlinear coordinate transformation to a white balance plane in order to characterize estimated illumination for the coactive neuro-fuzzy inference system model, wherein all parameters of fuzzy membership functions and local expert multilayer perceptrons are updated simultaneously.

40. The apparatus of claim 36, wherein the coactive neuro-fuzzy inference system model is trained by constructing fuzzy membership functions generated by applying a neural network nonlinear coordinate transformation to a white balance plane in order to characterize estimated illumination for the coactive neuro-fuzzy inference system model, wherein all parameters of fuzzy membership functions and local expert multilayer perceptrons are updated simultaneously in conjunction with a heuristic parameter updating rule.

41. The apparatus of claim 36, 37, 38, 39 or 40, wherein at least two of the fuzzy membership functions overlap.

42. An apparatus for correcting color of a color image obtained by an electronic camera, comprising:

a coactive neuro-fuzzy inference system with a switching unit for determining a correction to data representative of the color image based upon an estimated illuminant of the color image.

43. The apparatus of claim 33, wherein coactive neuro-fuzzy inference system model finds a color conversion inverse map using separate neural networks associated with respective representative sources of illumination, and outputs an output color space of the color corrected image as a space not normalized with chromaticity coordinates the sources of illumination.

44. The apparatus of claim 33, wherein coactive neuro-fuzzy inference system model finds a color conversion inverse map using neural networks associated with respective representative sources of illumination, and outputs an output color space of the color corrected image as a space not normalized with chromaticity coordinates the sources of illumination.

45. The apparatus of claim 33, wherein coactive neuro-fuzzy inference system model finds a color conversion inverse map using separate neural networks associated with respective representative sources of illumination, and uses training data of each neural network as a colorimetric value under a standard source of illumination.

46. The apparatus of claim 33, wherein coactive neuro-fuzzy inference system model finds a color conversion inverse map using neural networks associated with respective representative sources of illumination, and uses training data of each neural network as a colorimetric value under a standard source of illumination.

47. A recording medium having recorded thereon color corrected data of a color image obtained by an electronic camera, the recording medium being prepared by the steps of:

determining, using a neural network, a correction to data representative of the color image based upon an estimated illuminant of the color image;

applying the correction to the data representative of the color image, wherein the illuminant comprises multiple sources of illumination; and

recording on the recording medium data representative of the corrected data.

48. The recording medium 47, wherein the electronic camera captures at least one still image.

49. The recording medium of claim 47, wherein the electronic camera captures a succession of moving images.

50. A recording medium having recorded thereon color corrected data of a color image obtained by an electronic camera, the recording medium being prepared by the steps of:

determining, using a multilayer perceptron model, a correction to data representative of the color image based upon an estimated illuminant of the color image;

applying the correction to the data representative of the color image, wherein the illuminant comprises multiple sources of illumination; and

recording on the recording medium data representative of the corrected data.

51. The recording medium of claim 50, wherein the electronic camera captures at least one still image.

52. The recording medium of claim 50, wherein the electronic camera captures a succession of moving images.

53. The recording medium of claim 50, wherein the multilayer perceptron model is trained based upon a dogleg trust region implementation of a Levenberg-Marquardt type algorithm.

54. The recording medium of claim 54, further comprising the step of:

outputting an output color space of the color corrected image as a space not normalized with chromaticity coordinates the sources of illumination.

55. The recording medium of claim 50, further comprising the step of:

using training data of each neural network as a colorimetric value under a standard source of illumination.

56. A recording medium having recorded thereon color corrected data of a color image obtained by an electronic camera, the recording medium being prepared by the steps of:

determining, using a coactive neuro-fuzzy inference system model, a correction to data representative of the color image based upon an estimated illuminant of the color image;

applying the correction to the data representative of the color image, wherein the illuminant comprises multiple sources of illumination; and

recording on the recording medium data representative of the corrected data.

57. The recording medium of claim 56, wherein the electronic camera captures at least one still image.

58. The recording medium of claim 56, wherein the electronic camera captures a succession of moving images.

59. The recording medium of claim 56, wherein an integrating unit comprised of fuzzy membership functions computes a weighted sum of outputs of local expert multilayer perceptrons based upon an on-camera estimation of illumination at a time of color image capture.

60. The recording medium of claim 59, further comprising the step of:

constructing fuzzy membership functions by applying a neural network nonlinear coordinate transformation to a white balance plane in order to characterize estimated illumination for the coactive neuro-fuzzy inference system model.

61. The recording medium of claim 56, further comprising the step of:

training the coactive neuro-fuzzy inference system model by constructing fuzzy membership functions generated by applying a neural network nonlinear coordinate transformation to a white balance plane in order to characterize estimated illumination for the coactive neuro-fuzzy inference system model.

62. The recording medium of claim 59, further comprising the step of:

training the coactive neuro-fuzzy inference system model by constructing fuzzy membership functions generated by applying a neural network nonlinear coordinate transformation to a white balance plane in order to characterize estimated illumination for the coactive neuro-fuzzy inference system model, wherein all parameters of fuzzy membership functions and local expert multilayer perceptrons are updated simultaneously.

63. The recording medium of claim 59, further comprising the step of:

training the coactive neuro-fuzzy inference system model by constructing fuzzy membership functions generated by applying a neural network nonlinear coordinate transformation to a white balance plane in order to characterize estimated illumination for the coactive neuro-fuzzy inference system model, wherein all parameters of fuzzy membership functions and local expert multilayer perceptrons are updated simultaneously in conjunction with a heuristic parameter updating rule.

64. The recording medium of claim 59, 60, 61, 62 or 63, wherein at least two of the fuzzy membership functions overlap.

65. A recording medium having recorded thereon color corrected data of a color image obtained by an electronic camera, the recording medium being prepared by the steps of:

determining, using a coactive neuro-fuzzy inference system with a switching unit, a correction to data representative of the color image based upon an estimated illuminant of the color image; and

recording on the recording medium data representative of the corrected data.

66. The recording medium of claim 56, further comprising the steps of:

finding a color conversion inverse map using separate neural networks associated with respective representative sources of illumination; and

outputting an output color space of the color corrected image as a space not normalized with chromaticity coordinates the sources of illumination.

67. The recording medium of claim 56, further comprising the steps of:

finding a color conversion inverse map using neural networks associated with respective representative sources of illumination; and

outputting an output color space of the color corrected image as a space not normalized with chromaticity coordinates the sources of illumination.

68. The recording medium of claim 56, further comprising the steps of:

finding a color conversion inverse map using separate neural networks associated with respective representative sources of illumination; and

using training data of each neural network as a colorimetric value under a standard source of illumination.

69. The recording medium of claim 56, further comprising the steps of:

finding a color conversion inverse map using neural networks associated with respective representative sources of illumination; and

using training data of each neural network as a colorimetric value under a standard source of illumination.

70. A method of transmitting color corrected data of a color image obtained by an electronic camera, comprising the steps of:

determining, using a neural network, a correction to data representative of the color image based upon an estimated illuminant of the color image;

applying the correction to the data representative of the color image, wherein the illuminant comprises multiple sources of illumination; and

transmitting data representative of the corrected data.

71. The method of claim 70, wherein the electronic camera captures at least one still image.

72. The method of claim 70, wherein the electronic camera captures a succession of moving images.

73. A method of transmitting color corrected data of a color image obtained by an electronic camera, comprising the steps of:

determining, using a multilayer perceptron model, a correction to data representative of the color image based upon an estimated illuminant of the color image;

applying the correction to the data representative of the color image, wherein the illuminant comprises multiple sources of illumination; and

transmitting data representative of the corrected data.

74. The method of claim 73, wherein the electronic camera captures at least one still image.

75. The method of claim 73, wherein the electronic camera captures a succession of moving images.

76. The method of claim 73, wherein the multilayer perceptron model is trained based upon a dogleg trust region implementation of a Levenberg-Marquardt type algorithm.

77. The method of claim 73, further comprising the step of:

outputting an output color space of the color corrected image as a space not normalized with chromaticity coordinates the sources of illumination.

78. The method of claim 79, further comprising the step of:

using training data of each neural network as a colorimetric value under a standard source of illumination.

79. A method of transmitting color corrected data of a color image obtained by an electronic camera, comprising the steps of:

determining, using a coactive neuro-fuzzy inference system model, a correction to data representative of the color image based upon an estimated illuminant of the color image;

applying the correction to the data representative of the color image, wherein the illuminant comprises multiple sources of illumination; and

transmitting data representative of the corrected data.

80. The method of claim 79, wherein the electronic camera captures at least one still image.

81. The method of claim 79, wherein the electronic camera captures a succession of moving images.

82. The method of claim 79, wherein an integrating unit comprised of fuzzy membership functions computes a weighted sum of outputs of local expert multilayer perceptrons based upon an on-camera estimation of illumination at a time of color image capture.

83. The method of claim 82, further comprising the step of:

constructing fuzzy membership functions by applying a neural network nonlinear coordinate transformation to a white balance plane in order to characterize estimated illumination for the coactive neuro-fuzzy inference system model.

84. The method of claim 79, further comprising the step of:

training the coactive neuro-fuzzy inference system model by constructing fuzzy membership functions generated by applying a neural network nonlinear coordinate

transformation to a white balance plane in order to characterize estimated illumination for the coactive neuro-fuzzy inference system model.

85. The method of claim 82, further comprising the step of: training the coactive neuro-fuzzy inference system model by constructing fuzzy membership functions generated by applying a neural network nonlinear coordinate transformation to a white balance plane in order to characterize estimated illumination for the coactive neuro-fuzzy inference system model, wherein all parameters of fuzzy membership functions and local expert multilayer perceptrons are updated simultaneously.

86. The method of claim 82, further comprising the step of: training the coactive neuro-fuzzy inference system model by constructing fuzzy membership functions generated by applying a neural network nonlinear coordinate transformation to a white balance plane in order to characterize estimated illumination for the coactive neuro-fuzzy inference system model, wherein all parameters of fuzzy membership functions and local expert multilayer perceptrons are updated simultaneously in conjunction with a heuristic parameter updating rule.

87. The method of claim 82, 83, 84, 85 or 86 wherein at least two of the fuzzy membership functions overlap.

88. A method of transmitting color corrected data of a color image obtained by an electronic camera, comprising the steps of:

determining, using a coactive neuro-fuzzy inference system with a switching unit, a correction to data representative of the color image based upon an estimated illuminant of the color image; and

transmitting data representative of the corrected data.

89. The method of claim 79, further comprising the steps of:

finding a color conversion inverse map using separate neural networks associated with respective representative sources of illumination; and

outputting an output color space of the color corrected image as a space not normalized with chromaticity coordinates the sources of illumination.

90. The method of claim 79, further comprising the steps of:

finding a color conversion inverse map using neural networks associated with respective representative sources of illumination; and

outputting an output color space of the color corrected image as a space not normalized with chromaticity coordinates the sources of illumination.

91. The method of claim 79, further comprising the steps of:

finding a color conversion inverse map using separate neural networks associated with respective representative sources of illumination; and

using training data of each neural network as a colorimetric value under a standard source of illumination.

92. The method of claim 79, further comprising the steps of:

finding a color conversion inverse map using neural networks associated with respective representative sources of illumination; and

using training data of each neural network as a colorimetric value under a standard source of illumination.

93. The method of claim 1, 4 or 10, wherein the data representative of the color image includes information regarding the illuminant.

94. The apparatus of claim 24, 27 or 33, wherein the data representative of the color image includes information regarding the illuminant.

95. A method of recording image data obtained by an electronic camera, comprising the steps of:

capturing a color image and generating data representative of the image;

estimating an illuminant for the captured color image and generating data representative of the estimated illuminant; and

recording the data representative of the image with the data representative of the estimated illuminant.

96. A method of transmitting image data obtained by an electronic camera, comprising the steps of:

capturing a color image and generating data representative of the image;

estimating an illuminant for the captured color image and generating data representative of the estimated illuminant; and

transmitting the data representative of the image with the data representative of the estimated illuminant.

AMENDED CLAIMS

[received by the International Bureau on 18 September 2000 (18.09.00);
original claim 20-23, 43-46, 66-69 and 89-92 amended;
remaining claims unchanged (23 pages)]

1. A method of correcting color of a color image obtained by an electronic camera, comprising the steps of:

determining, using a neural network, a correction to data representative of the color image based upon an estimated illuminant of the color image; and

applying the correction to the data representative of the color image, wherein the illuminant comprises multiple sources of illumination.

2. The method of claim 1, wherein the electronic camera captures at least one still image.

3. The method of claim 1, wherein the electronic camera captures a succession of moving images.

4. A method of correcting color of a color image obtained by an electronic camera, comprising the steps of:

determining, using a multilayer perceptron model, a correction to data representative of the color image based upon an estimated illuminant of the color image; and

applying the correction to the data representative of the color image, wherein the illuminant comprises multiple sources of illumination.

5. The method of claim 4, wherein the electronic camera captures at least one still image.

6. The method of claim 4, wherein the electronic camera captures a succession of moving images.

7. The method of claim 4, wherein the multilayer perceptron model is trained based upon a dogleg trust region implementation of a Levenberg-Marquardt type algorithm.

8. The method of claim 4, further comprising the step of:

outputting an output color space of the color corrected image as a space not normalized with chromaticity coordinates the sources of illumination.

9. The method of claim 4, further comprising the step of:

using training data of each neural network as a colorimetric value under a standard source of illumination.

10. A method of correcting color of a color image obtained by an electronic camera, comprising the steps of:

determining, using a coactive neuro-fuzzy inference system model, a correction to data representative of the color image based upon an estimated illuminant of the color image; and

applying the correction to the data representative of the color image, wherein the illuminant comprises multiple sources of illumination.

11. The method of claim 10, wherein the electronic camera captures at least one still image.

12. The method of claim 10, wherein the electronic camera captures a succession of moving images.

13. The method of claim 10, wherein an integrating unit comprised of fuzzy membership functions computes a weighted sum of outputs of local expert multilayer perceptrons based upon an on-camera estimation of illumination at a time of color image capture.

14. The method of claim 13, further comprising the step of:

constructing fuzzy membership functions by applying a neural network nonlinear coordinate transformation to a white balance plane in order to characterize estimated illumination for the coactive neuro-fuzzy inference system model.

15. The method of claim 10, further comprising the step of:

training the coactive neuro-fuzzy inference system model by constructing fuzzy membership functions generated by applying a neural network nonlinear coordinate transformation to a white balance plane in order to characterize estimated illumination for the coactive neuro-fuzzy inference system model.

16. The method of claim 13, further comprising the step of:

training the coactive neuro-fuzzy inference system model by constructing fuzzy membership functions generated by applying a neural network nonlinear coordinate transformation to a white balance plane in order to characterize estimated illumination for the coactive neuro-fuzzy inference system model, wherein all parameters of fuzzy

membership functions and local expert multilayer perceptrons are updated simultaneously.

17. The method of claim 13, further comprising the step of:

training the coactive neuro-fuzzy inference system model by constructing fuzzy membership functions generated by applying a neural network nonlinear coordinate transformation to a white balance plane in order to characterize estimated illumination for the coactive neuro-fuzzy inference system model, wherein all parameters of fuzzy membership functions and local expert multilayer perceptrons are updated simultaneously in conjunction with a heuristic parameter updating rule.

18. The method of claim 13, 14, 15, 16 or 17, wherein at least two of the fuzzy membership functions overlap.

19. A method of correcting color of a color image obtained by an electronic camera, comprising the steps of:

determining, using a coactive neuro-fuzzy inference system with a switching unit, a correction to data representative of the color image based upon an estimated illuminant of the color image.

20. The method of claim 10, further comprising the steps of:

finding a color conversion inverse map using a plurality of neural networks associated with respective representative sources of illumination;

using a respective subset of training data to independently train each neural network in a component-wise manner, wherein each of the neural networks is a local expert neural network; and

outputting an output color space of the color corrected image as a space with chromaticity coordinates of the sources of illumination.

21. The method of claim 10, further comprising the steps of:

finding a color conversion inverse map using a plurality of neural networks associated with respective representative sources of illumination;

using an entire training data set to simultaneously train all of the neural networks in a system-wise manner, wherein the neural networks are local expert neural networks; and

outputting an output color space of the color corrected image as a space with chromaticity coordinates of the sources of illumination.

22. The method of claim 10, further comprising the steps of:

finding a color conversion inverse map using neural networks associated with respective representative sources of illumination; and

using a respective subset of training data to independently train each neural network in a component-wise manner, wherein each of the neural networks is a local expert neural network.

23. The method of claim 10, further comprising the steps of:

finding a color conversion inverse map using neural networks associated with respective representative sources of illumination; and

using an entire training data set to simultaneously train all of the neural networks in a system-wise manner, wherein the neural networks are local expert neural networks.

24. An apparatus for correcting color of a color image obtained by an electronic camera, comprising:

a neural network for determining a correction to data representative of the color image based upon an estimated illuminant of the color image and for applying the correction to the data representative of the color image, wherein the illuminant comprises multiple sources of illumination.

25. The apparatus of claim 24, wherein the electronic camera captures at least one still image.

26. The apparatus of claim 24, wherein the electronic camera captures a succession of moving images.

27. An apparatus for correcting color of a color image obtained by an electronic camera, comprising:

a multilayer perceptron model for determining a correction to data representative of the color image based upon an estimated illuminant of the color image, and for

applying the correction to the data representative of the color image, wherein the illuminant comprises multiple sources of illumination.

28. The apparatus of claim 27, wherein the electronic camera captures at least one still image.

29. The apparatus of claim 27, wherein the electronic camera captures a succession of moving images.

30. The apparatus of claim 27, wherein the multilayer perceptron model is trained based upon a dogleg trust region implementation of a Levenberg-Marquardt type algorithm.

31. The apparatus of claim 27, wherein the multilayer perceptron model outputs an output color space of the color corrected image as a space not normalized with chromaticity coordinates the sources of illumination.

32. The apparatus of claim 27, wherein the multilayer perceptron model uses training data of each neural network as a colorimetric value under a standard source of illumination.

33. An apparatus for correcting color of a color image obtained by an electronic camera, comprising:

a coactive neuro-fuzzy inference system model for determining a correction to data representative of the color image based upon an estimated illuminant of the color image, and for applying the correction to the data representative of

the color image, wherein the illuminant comprises multiple sources of illumination.

34. The apparatus of claim 33, wherein the electronic camera captures at least one still image.

35. The apparatus of claim 33, wherein the electronic camera captures a succession of moving images.

36. The apparatus of claim 33, wherein an integrating unit comprised of fuzzy membership functions computes a weighted sum of outputs of local expert multilayer perceptrons based upon an on-camera estimation of illumination at a time of color image capture.

37. The apparatus of claim 36, wherein fuzzy membership functions are constructed by applying a neural network nonlinear coordinate transformation to a white balance plane in order to characterize estimated illumination for the coactive neuro-fuzzy inference system model.

38. The apparatus of claim 33, wherein the coactive neuro-fuzzy inference system model is trained by constructing fuzzy membership functions generated by applying a neural network nonlinear coordinate transformation to a white balance plane in order to characterize estimated illumination for the coactive neuro-fuzzy inference system model.

39. The apparatus of claim 36, wherein the coactive neuro-fuzzy inference system model is trained by constructing fuzzy

membership functions generated by applying a neural network nonlinear coordinate transformation to a white balance plane in order to characterize estimated illumination for the coactive neuro-fuzzy inference system model, wherein all parameters of fuzzy membership functions and local expert multilayer perceptrons are updated simultaneously.

40. The apparatus of claim 36, wherein the coactive neuro-fuzzy inference system model is trained by constructing fuzzy membership functions generated by applying a neural network nonlinear coordinate transformation to a white balance plane in order to characterize estimated illumination for the coactive neuro-fuzzy inference system model, wherein all parameters of fuzzy membership functions and local expert multilayer perceptrons are updated simultaneously in conjunction with a heuristic parameter updating rule.

41. The apparatus of claim 36, 37, 38, 39 or 40, wherein at least two of the fuzzy membership functions overlap.

42. An apparatus for correcting color of a color image obtained by an electronic camera, comprising:

a coactive neuro-fuzzy inference system with a switching unit for determining a correction to data representative of the color image based upon an estimated illuminant of the color image.

43. The apparatus of claim 33, wherein the coactive neuro-fuzzy inference system model finds a color conversion inverse map

using a plurality of neural networks associated with respective representative sources of illumination, uses a respective subset of training data to independently train each neural network in a component-wise manner, wherein each of the neural networks is a local expert neural network, and outputs an output color space of the color corrected image as a space with chromaticity coordinates of the sources of illumination.

44. The apparatus of claim 33, wherein the coactive neuro-fuzzy inference system model finds a color conversion inverse map using a plurality of neural networks associated with respective representative sources of illumination, uses an entire training data set to simultaneously train all of the neural networks in a system-wise manner, wherein the neural networks are local expert neural networks, and outputs an output color space of the color corrected image as a space with chromaticity coordinates of the sources of illumination.

45. The apparatus of claim 33, wherein the coactive neuro-fuzzy inference system model finds a color conversion inverse map using neural networks associated with respective representative sources of illumination, and uses a respective subset of training data to independently train each neural network in a component-wise manner, wherein each of the neural networks is a local expert neural network.

46. The apparatus of claim 33, wherein the coactive neuro-fuzzy inference system model finds a color conversion inverse map using neural networks associated with respective representative

sources of illumination, and uses an entire training data set to simultaneously train all of the neural networks in a system-wise manner, wherein the neural networks are local expert neural networks.

47. A recording medium having recorded thereon color corrected data of a color image obtained by an electronic camera, the recording medium being prepared by the steps of:

determining, using a neural network, a correction to data representative of the color image based upon an estimated illuminant of the color image;

applying the correction to the data representative of the color image, wherein the illuminant comprises multiple sources of illumination; and

recording on the recording medium data representative of the corrected data.

48. The recording medium 47, wherein the electronic camera captures at least one still image.

49. The recording medium of claim 47, wherein the electronic camera captures a succession of moving images.

50. A recording medium having recorded thereon color corrected data of a color image obtained by an electronic camera, the recording medium being preoared by the steps of:

determining, using a multilayer perceptron model, a correction to data representative of the color image based upon an estimated illuminant of the color image;

applying the correction to the data representative of the color image, wherein the illuminant comprises multiple sources of illumination; and

recording on the recording medium data representative of the corrected data.

51. The recording medium of claim 50, wherein the electronic camera captures at least one still image.

52. The recording medium of claim 50, wherein the electronic camera captures a succession of moving images.

53. The recording medium of claim 50, wherein the multilayer perceptron model is trained based upon a dogleg trust region implementation of a Levenberg-Marquardt type algorithm.

54. The recording medium of claim 54, further comprising the step of:

outputting an output color space of the color corrected image as a space not normalized with chromaticity coordinates the sources of illumination.

55. The recording medium of claim 50, further comprising the step of:

using training data of each neural network as a colorimetric value under a standard source of illumination.

56. A recording medium having recorded thereon color corrected data of a color image obtained by an electronic camera, the recording medium being prepared by the steps of:

determining, using a coactive neuro-fuzzy inference system model, a correction to data representative of the color image based upon an estimated illuminant of the color image;

applying the correction to the data representative of the color image, wherein the illuminant comprises multiple sources of illumination; and

recording on the recording medium data representative of the corrected data.

57. The recording medium of claim 56, wherein the electronic camera captures at least one still image.

58. The recording medium of claim 56, wherein the electronic camera captures a succession of moving images.

59. The recording medium of claim 56, wherein an integrating unit comprised of fuzzy membership functions computes a weighted sum of outputs of local expert multilayer perceptrons based upon an on-camera estimation of illumination at a time of color image capture.

60. The recording medium of claim 59, further comprising the step of:

constructing fuzzy membership functions by applying a neural network nonlinear coordinate transformation to a white

balance plane in order to characterize estimated illumination for the coactive neuro-fuzzy inference system model.

61. The recording medium of claim 56, further comprising the step of:

training the coactive neuro-fuzzy inference system model by constructing fuzzy membership functions generated by applying a neural network nonlinear coordinate transformation to a white balance plane in order to characterize estimated illumination for the coactive neuro-fuzzy inference system model.

62. The recording medium of claim 59, further comprising the step of:

training the coactive neuro-fuzzy inference system model by constructing fuzzy membership functions generated by applying a neural network nonlinear coordinate transformation to a white balance plane in order to characterize estimated illumination for the coactive neuro-fuzzy inference system model, wherein all parameters of fuzzy membership functions and local expert multilayer perceptrons are updated simultaneously.

63. The recording medium of claim 59, further comprising the step of:

training the coactive neuro-fuzzy inference system model by constructing fuzzy membership functions generated by applying a neural network nonlinear coordinate transformation to a white balance plane in order to

characterize estimated illumination for the coactive neuro-fuzzy inference system model, wherein all parameters of fuzzy membership functions and local expert multilayer perceptrons are updated simultaneously in conjunction with a heuristic parameter updating rule.

64. The recording medium of claim 59, 60, 61, 62 or 63, wherein at least two of the fuzzy membership functions overlap.

65. A recording medium having recorded thereon color corrected data of a color image obtained by an electronic camera, the recording medium being prepared by the steps of:

determining, using a coactive neuro-fuzzy inference system with a switching unit, a correction to data representative of the color image based upon an estimated illuminant of the color image; and

recording on the recording medium data representative of the corrected data.

66. The recording medium of claim 56, further comprising the steps of:

finding a color conversion inverse map using a plurality of neural networks associated with respective representative sources of illumination;

using a respective subset of training data to independently train each neural network in a component-wise manner, wherein each of the neural networks is a local expert neural network; and

outputting an output color space of the color corrected

image as a space with chromaticity coordinates of the sources of illumination.

67. The recording medium of claim 56, further comprising the steps of:

finding a color conversion inverse map using a plurality of neural networks associated with respective representative sources of illumination;

using an entire training data set to simultaneously train all of the neural networks in a system-wise manner, wherein the neural networks are local expert neural networks; and

outputting an output color space of the color corrected image as a space with chromaticity coordinates of the sources of illumination.

68. The recording medium of claim 56, further comprising the steps of:

finding a color conversion inverse map using neural networks associated with respective representative sources of illumination; and

using a respective subset of training data to independently train each neural network in a component-wise manner, wherein each of the neural networks is a local expert neural network.

69. The recording medium of claim 56, further comprising the steps of:

finding a color conversion inverse map using neural networks associated with respective representative sources of

illumination; and

using an entire training data set to simultaneously train all of the neural networks in a system-wise manner, wherein the neural networks are local expert neural networks.

70. A method of transmitting color corrected data of a color image obtained by an electronic camera, comprising the steps of:

determining, using a neural network, a correction to data representative of the color image based upon an estimated illuminant of the color image;

applying the correction to the data representative of the color image, wherein the illuminant comprises multiple sources of illumination; and

transmitting data representative of the corrected data.

71. The method of claim 70, wherein the electronic camera captures at least one still image.

72. The method of claim 70, wherein the electronic camera captures a succession of moving images.

73. A method of transmitting color corrected data of a color image obtained by an electronic camera, comprising the steps of:

determining, using a multilayer perceptron model, a correction to data representative of the color image based upon an estimated illuminant of the color image;

applying the correction to the data representative of the color image, wherein the illuminant comprises multiple sources of illumination; and

transmitting data representative of the corrected data.

74. The method of claim 73, wherein the electronic camera captures at least one still image.

75. The method of claim 73, wherein the electronic camera captures a succession of moving images.

76. The method of claim 73, wherein the multilayer perceptron model is trained based upon a dogleg trust region implementation of a Levenberg-Marquardt type algorithm.

77. The method of claim 73, further comprising the step of:

outputting an output color space of the color corrected image as a space not normalized with chromaticity coordinates the sources of illumination.

78. The method of claim 79, further comprising the step of:

using training data of each neural network as a colorimetric value under a standard source of illumination.

79. A method of transmitting color corrected data of a color image obtained by an electronic camera, comprising the steps of:

determining, using a coactive neuro-fuzzy inference system model, a correction to data representative of the color image based upon an estimated illuminant of the color image;

applying the correction to the data representative of the color image, wherein the illuminant comprises multiple sources of illumination; and

transmitting data representative of the corrected data.

80. The method of claim 79, wherein the electronic camera captures at least one still image.

81. The method of claim 79, wherein the electronic camera captures a succession of moving images.

82. The method of claim 79, wherein an integrating unit comprised of fuzzy membership functions computes a weighted sum of outputs of local expert multilayer perceptrons based upon an on-camera estimation of illumination at a time of color image capture.

83. The method of claim 82, further comprising the step of:

constructing fuzzy membership functions by applying a neural network nonlinear coordinate transformation to a white balance plane in order to characterize estimated illumination for the coactive neuro-fuzzy inference system model.

84. The method of claim 79, further comprising the step of:

training the coactive neuro-fuzzy inference system model by constructing fuzzy membership functions generated by applying a neural network nonlinear coordinate transformation to a white balance plane in order to characterize estimated illumination for the coactive neuro-fuzzy inference system model.

85. The method of claim 82, further comprising the step of:

training the coactive neuro-fuzzy inference system model by constructing fuzzy membership functions generated by applying a neural network nonlinear coordinate transformation to a white balance plane in order to characterize estimated illumination for the coactive neuro-fuzzy inference system model, wherein all parameters of fuzzy membership functions and local expert multilayer perceptrons are updated simultaneously.

86. The method of claim 82, further comprising the step of:

training the coactive neuro-fuzzy inference system model by constructing fuzzy membership functions generated by applying a neural network nonlinear coordinate transformation to a white balance plane in order to characterize estimated illumination for the coactive neuro-fuzzy inference system model, wherein all parameters of fuzzy membership functions and local expert multilayer perceptrons are updated simultaneously in conjunction with a heuristic parameter updating rule.

87. The method of claim 82, 83, 84, 85 or 86 wherein at least two of the fuzzy membership functions overlap.

88. A method of transmitting color corrected data of a color image obtained by an electronic camera, comprising the steps of:

determining, using a coactive neuro-fuzzy inference system with a switching unit, a correction to data representative of the color image based upon an estimated illuminant of the color image; and

transmitting data representative of the corrected data.

89. The method of claim 79, further comprising the steps of:

finding a color conversion inverse map using a plurality of neural networks associated with respective representative sources of illumination;

using a respective subset of training data to independently train each neural network in a component-wise manner, wherein each of the neural networks is a local expert neural network; and

outputting an output color space of the color corrected image as a space with chromaticity coordinates of the sources of illumination.

90. The method of claim 79, further comprising the steps of:

finding a color conversion inverse map using a plurality of neural networks associated with respective representative sources of illumination;

using an entire training data set to simultaneously train all of the neural networks in a system-wise manner, wherein the neural networks are local expert neural networks; and

outputting an output color space of the color corrected image as a space with chromaticity coordinates of the sources of illumination.

91. The method of claim 79, further comprising the steps of:

finding a color conversion inverse map using neural networks associated with respective representative sources of illumination; and

using a respective subset of training data to independently train each neural network in a component-wise manner, wherein each of the neural networks is a local expert neural network.

92. The method of claim 79, further comprising the steps of:

finding a color conversion inverse map using neural networks associated with respective representative sources of illumination; and

using an entire training data set to simultaneously train all of the neural networks in a system-wise manner, wherein the neural networks are local expert neural networks.

93. The method of claim 1, 4 or 10, wherein the data representative of the color image includes information regarding the illuminant.

94. The apparatus of claim 24, 27 or 33, wherein the data representative of the color image includes information regarding the illuminant.

95. A method of recording image data obtained by an electronic camera, comprising the steps of:

capturing a color image and generating data representative of the image;

estimating an illuminant for the captured color image and generating data representative of the estimated illuminant; and

recording the data representative of the image with the data representative of the estimated illuminant.

96. A method of transmitting image data obtained by an electronic camera, comprising the steps of:

capturing a color image and generating data representative of the image;

estimating an illuminant for the captured color image and generating data representative of the estimated illuminant; and

transmitting the data representative of the image with the data representative of the estimated illuminant.

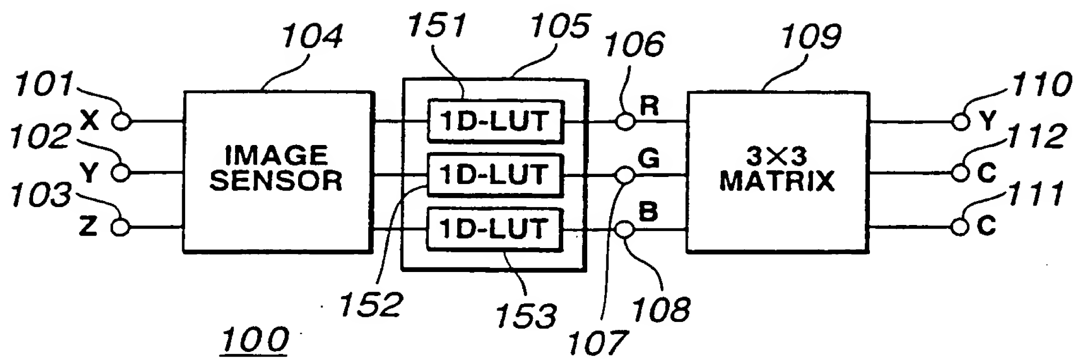

104
151
105
106
109
101
X
102
Y
103
Z
IMAGE SENSOR
1D-LUT
1D-LUT
1D-LUT
R
G
B
3×3 MATRIX
110
Y
112
C
111
C
152
153
107
108
100

FIG. 1

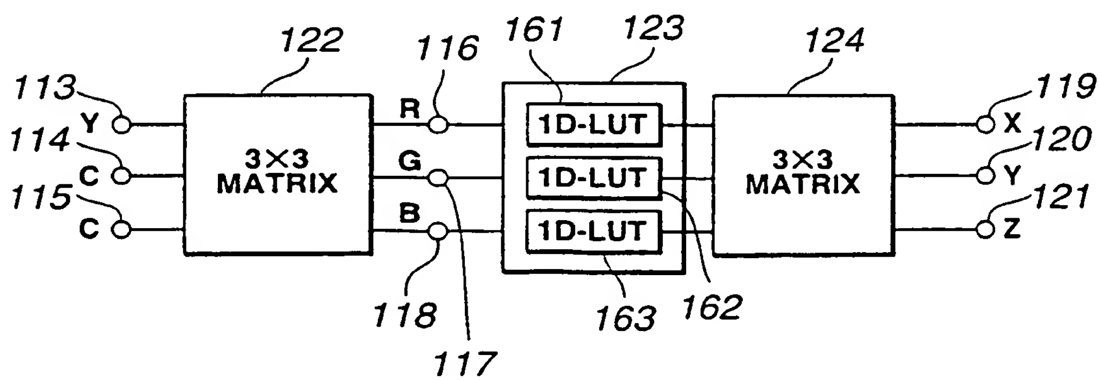

122
116
161
123
124
113
Y
114
C
115
C
3×3 MATRIX
R
G
B
1D-LUT
1D-LUT
1D-LUT
3×3 MATRIX
119
X
120
Y
121
Z
118
117
163
162

FIG. 2

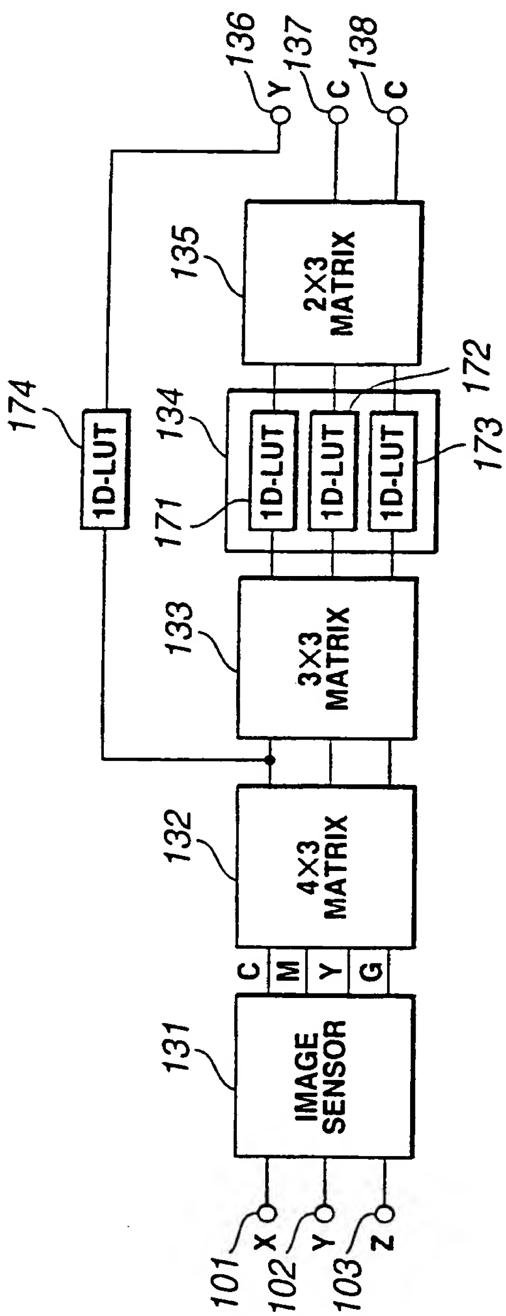

101
X
102
Y
103
Z
131
IMAGE SENSOR
C
M
Y
G
132
4×3 MATRIX
133
3×3 MATRIX
134
171
1D-LUT
172
1D-LUT
173
1D-LUT
174
1D-LUT
135
2×3 MATRIX
136
Y
137
C
138
C

FIG. 3

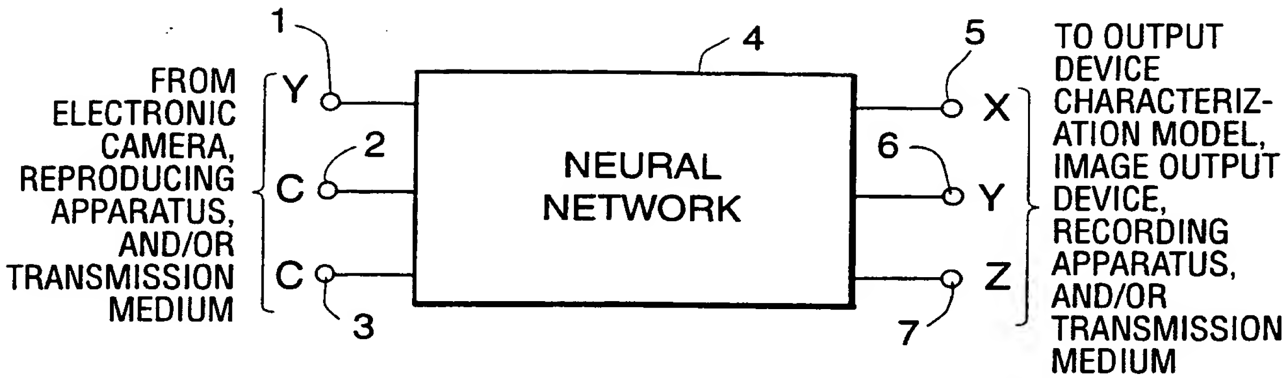
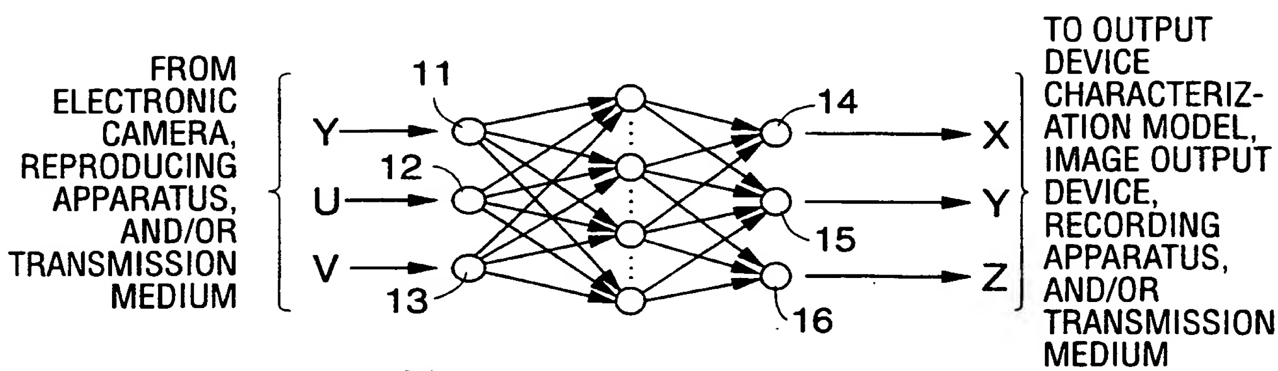


FIG. 4A



Multilayer perceptrons

FIG. 4B

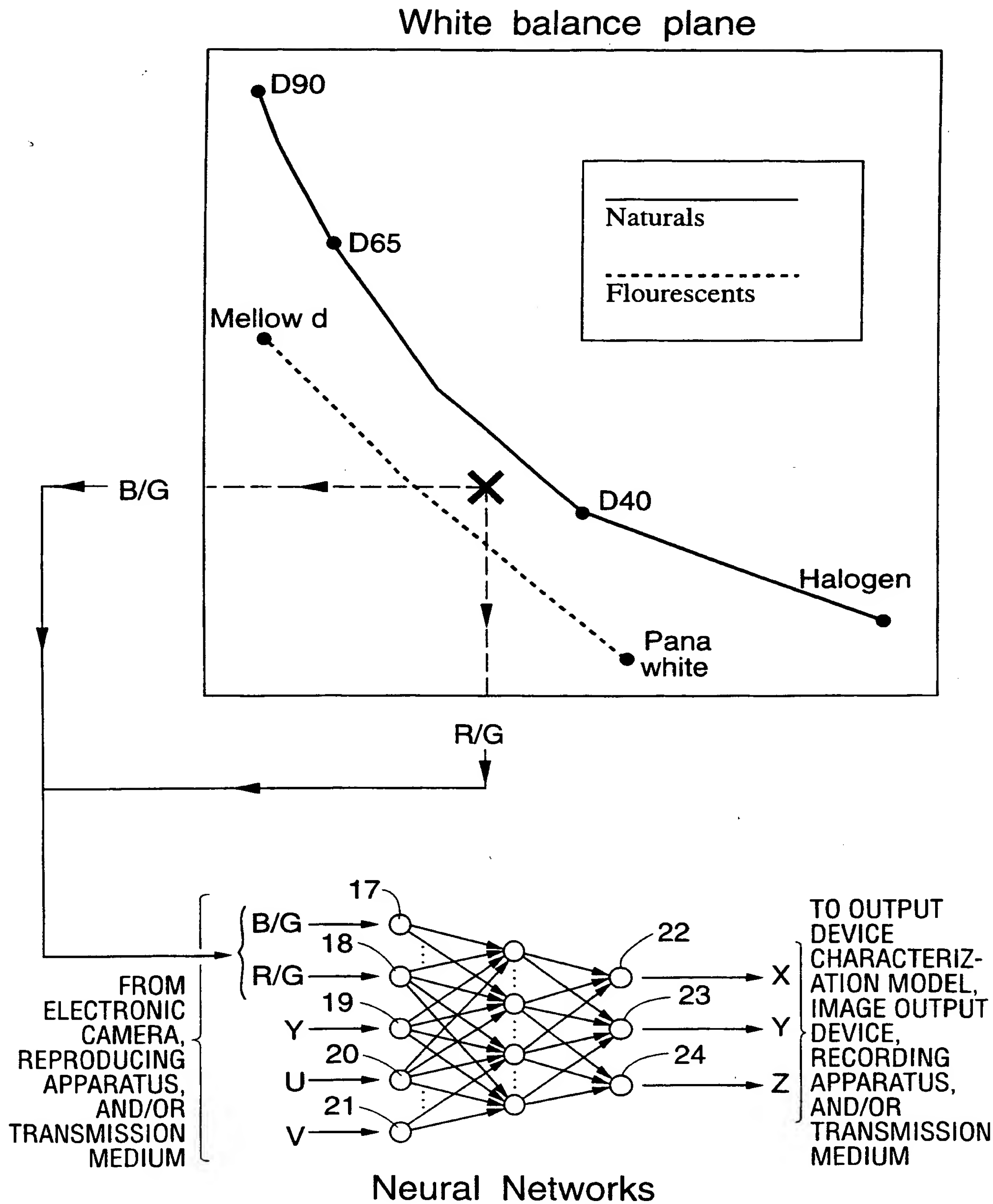

White balance plane
D90
D65
Mellow d
D40
Halogen
Pana white
Naturals
Flourescents
B/G
R/G
17
18
19
20
21
22
23
24
B/G
R/G
Y
U
V
X
Y
Z
FROM ELECTRONIC CAMERA, REPRODUCING APPARATUS, AND/OR TRANSMISSION MEDIUM
TO OUTPUT DEVICE CHARACTERIZ-ATION MODEL, IMAGE OUTPUT DEVICE, RECORDING APPARATUS, AND/OR TRANSMISSION MEDIUM
Neural Networks

FIG. 5

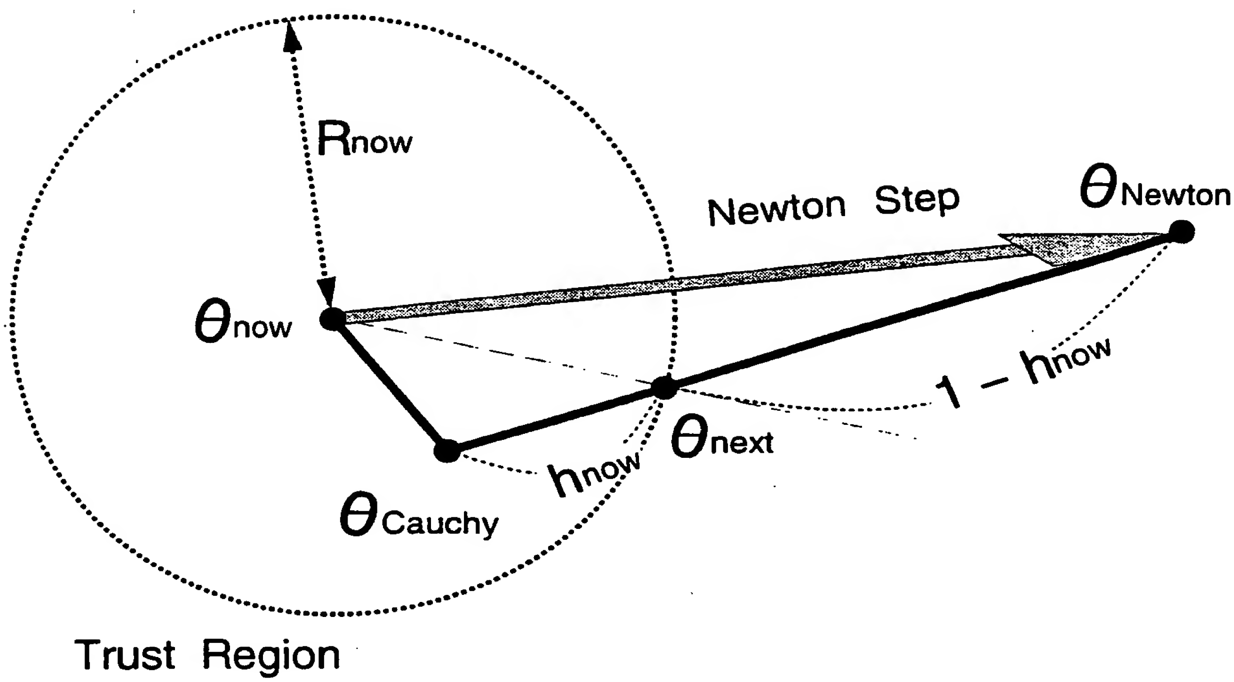

R_{now}
Newton Step
θ_{Newton}
θ_{now}
$1 - h_{now}$
θ_{next}
h_{now}
θ_{Cauchy}
Trust Region

FIG. 6A

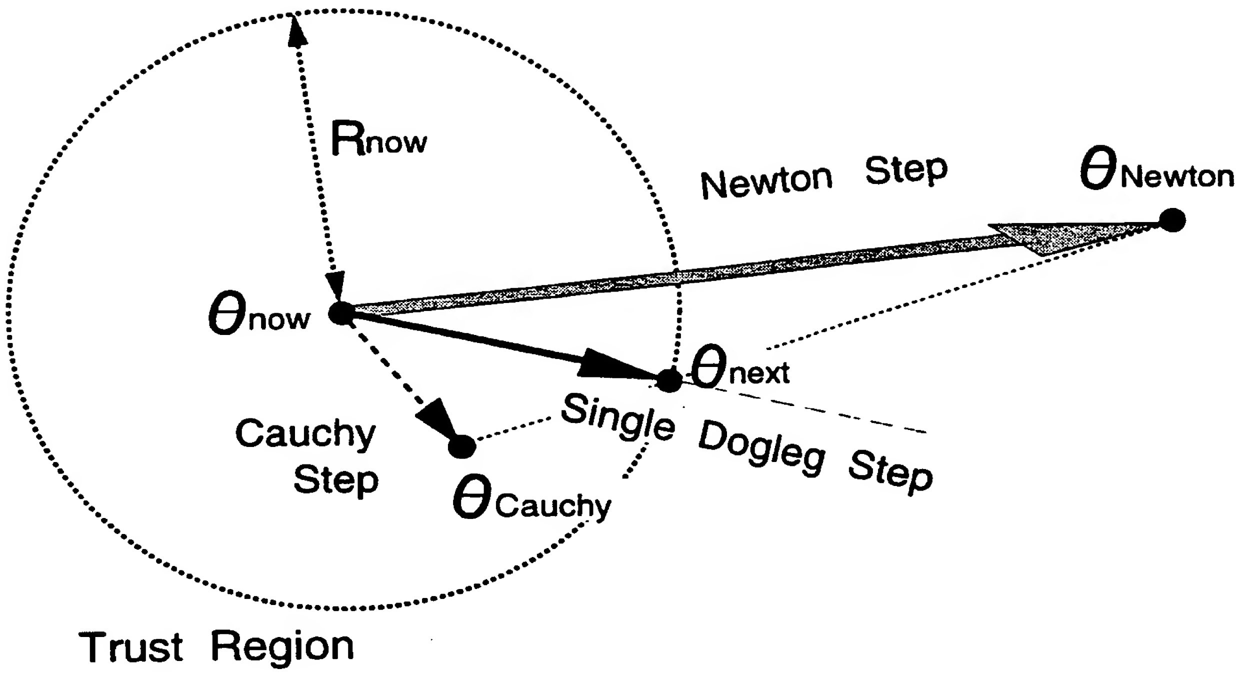

R_{now}
Newton Step
θ_{Newton}
θ_{now}
θ_{next}
Cauchy
Step
Single Dogleg Step
θ_{Cauchy}
Trust Region

FIG. 6B

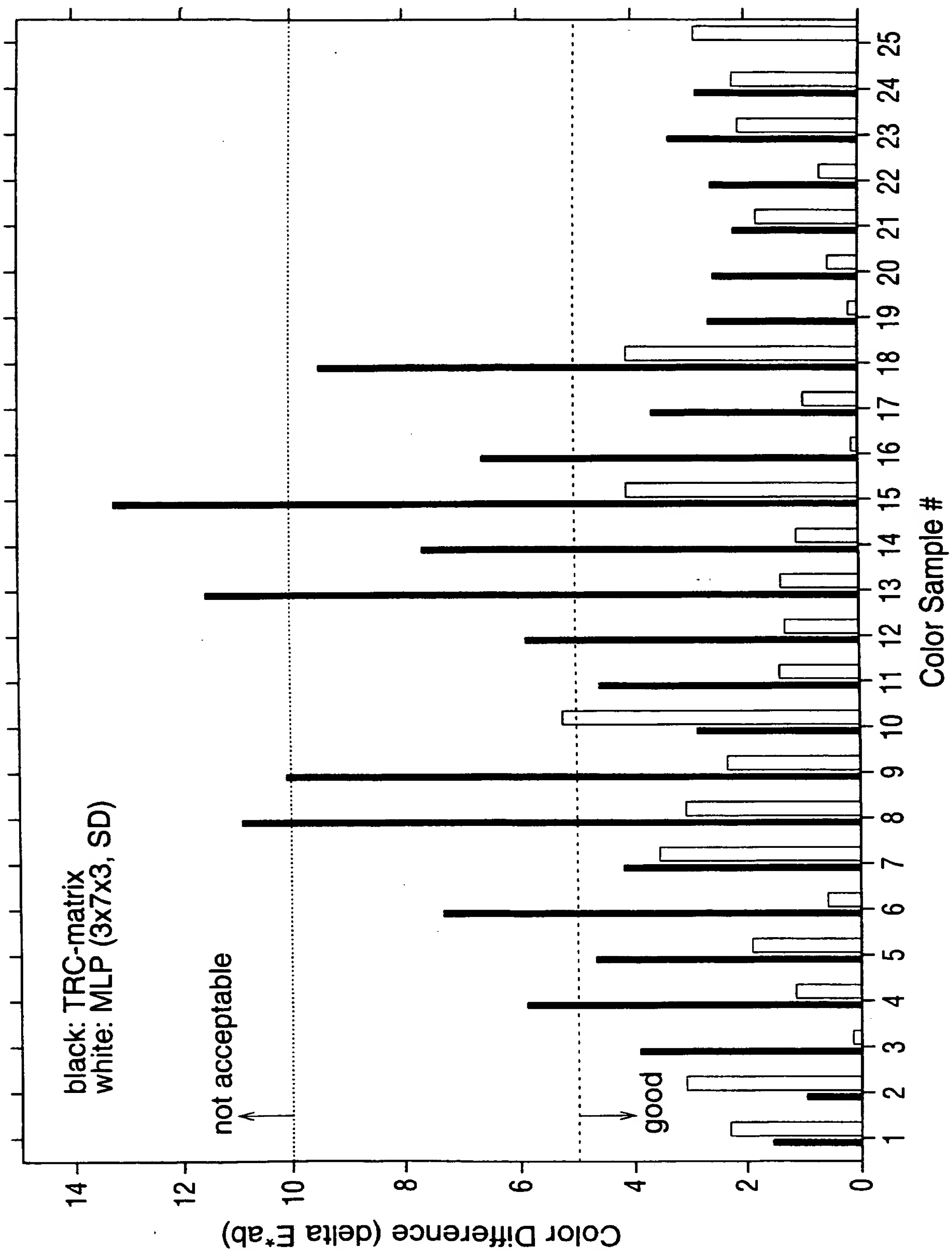

black: TRC-matrix
white: MLP (3x7x3, SD)
not acceptable
good
Color Difference (delta E*ab)
Color Sample #
0
2
4
6
8
10
12
14
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25

FIG. 7

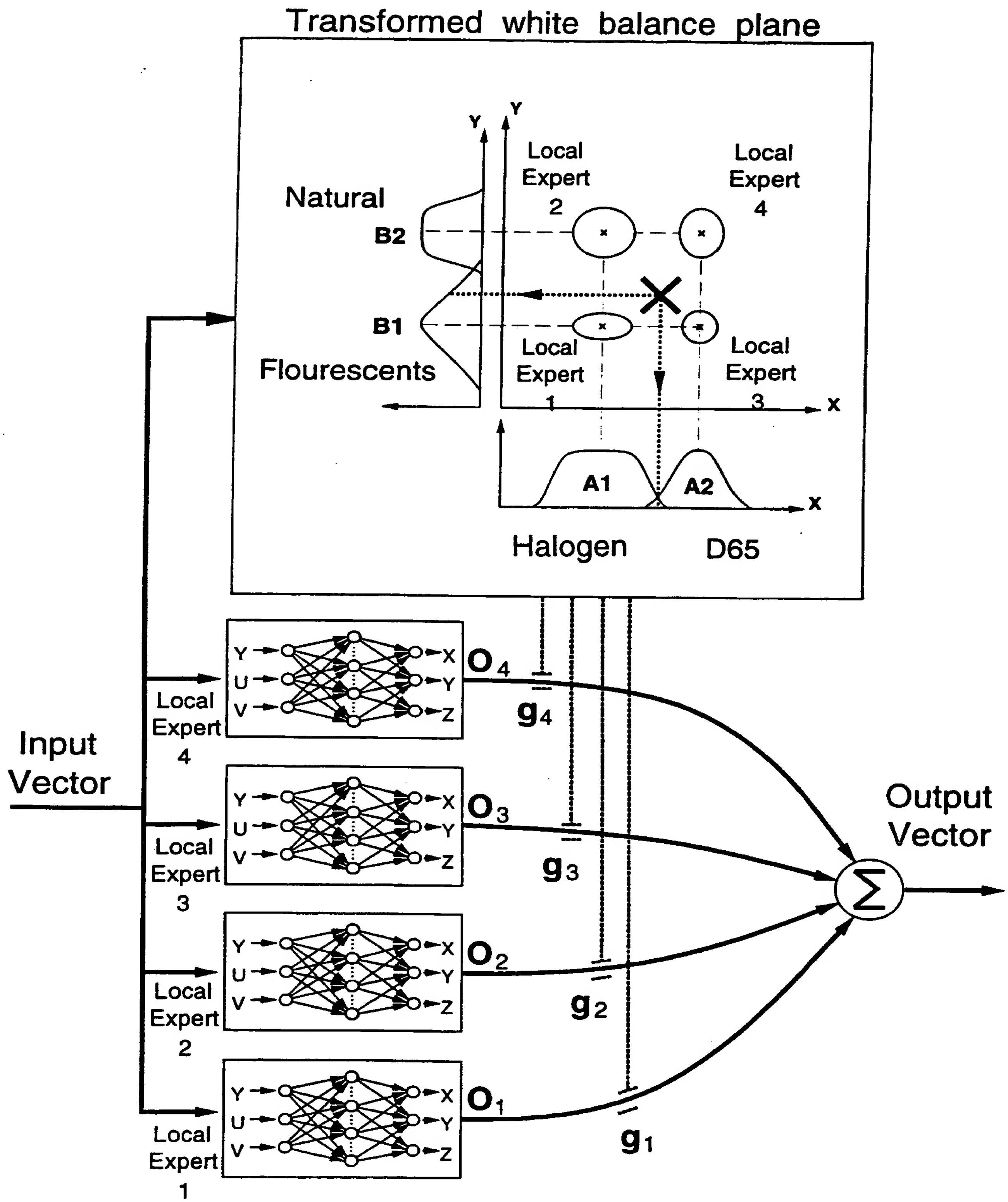

Transformed white balance plane
Y
Y
Local Expert 2
Local Expert 4
Natural
B2
B1
Flourescents
Local Expert 1
Local Expert 3
X
A1
A2
X
Halogen
D65
Input Vector
Y U V
X Y Z
O4
g4
Local Expert 4
O3
g3
Local Expert 3
O2
g2
Local Expert 2
O1
g1
Local Expert 1
Output Vector
Σ

FIG. 8

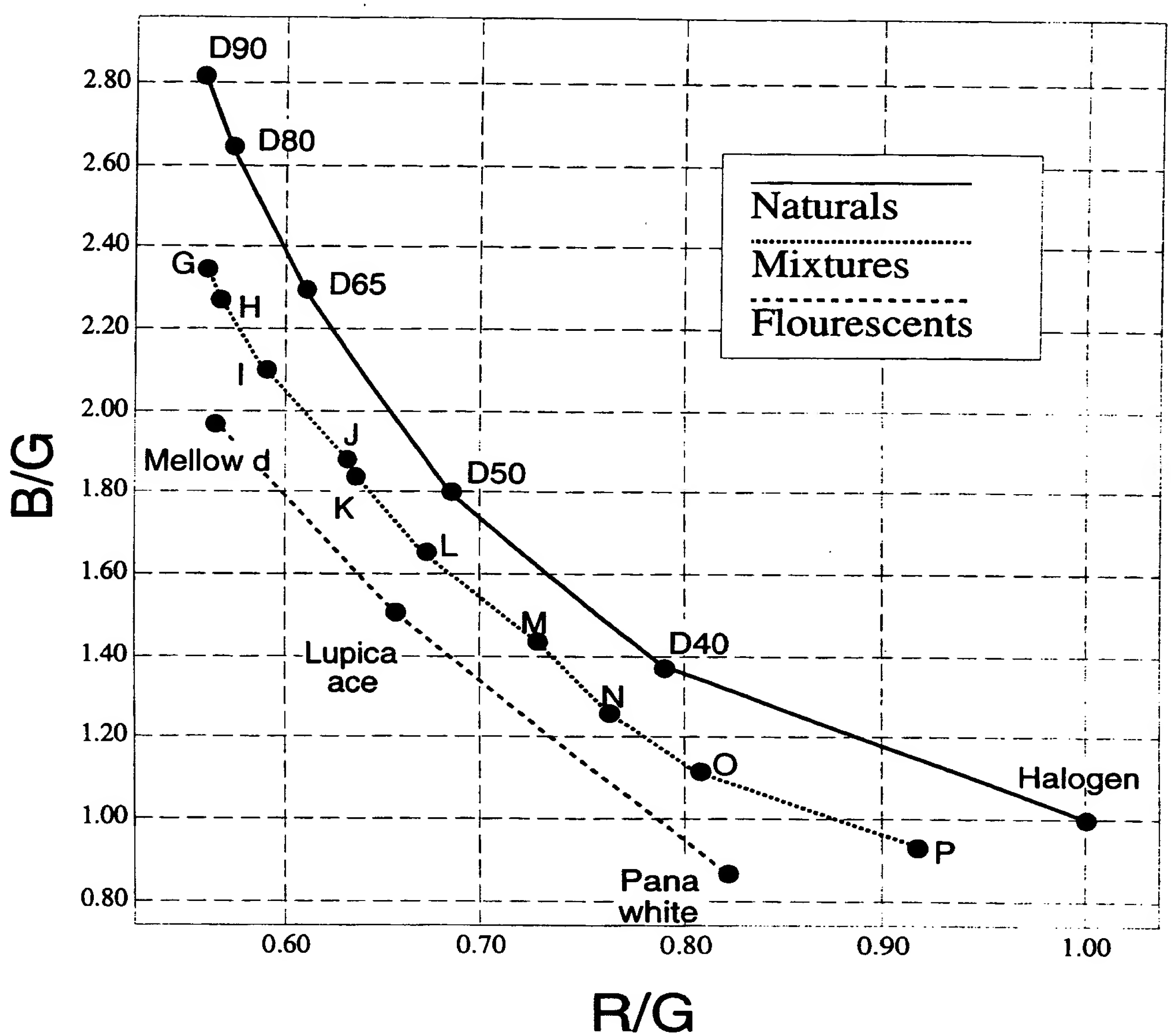

D90
D80
Naturals
Mixtures
Flourescents
G
H
D65
I
Mellow d
J
K
D50
L
M
D40
Lupica
ace
N
O
Halogen
P
Pana
white
2.80
2.60
2.40
2.20
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.70
0.80
0.90
1.00
B/G
R/G

FIG. 9

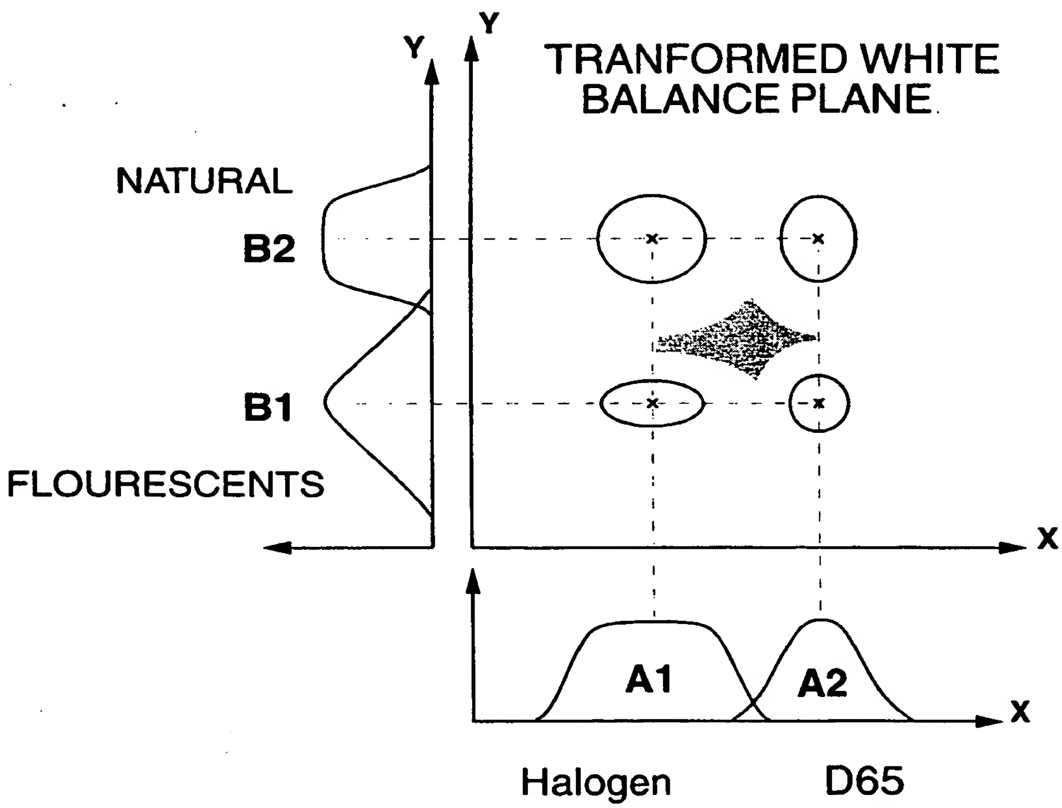

Y
Y
TRANFORMED WHITE
BALANCE PLANE
NATURAL
B2
B1
FLOURESCENTS
X
A1
A2
X
Halogen
D65

FIG. 10

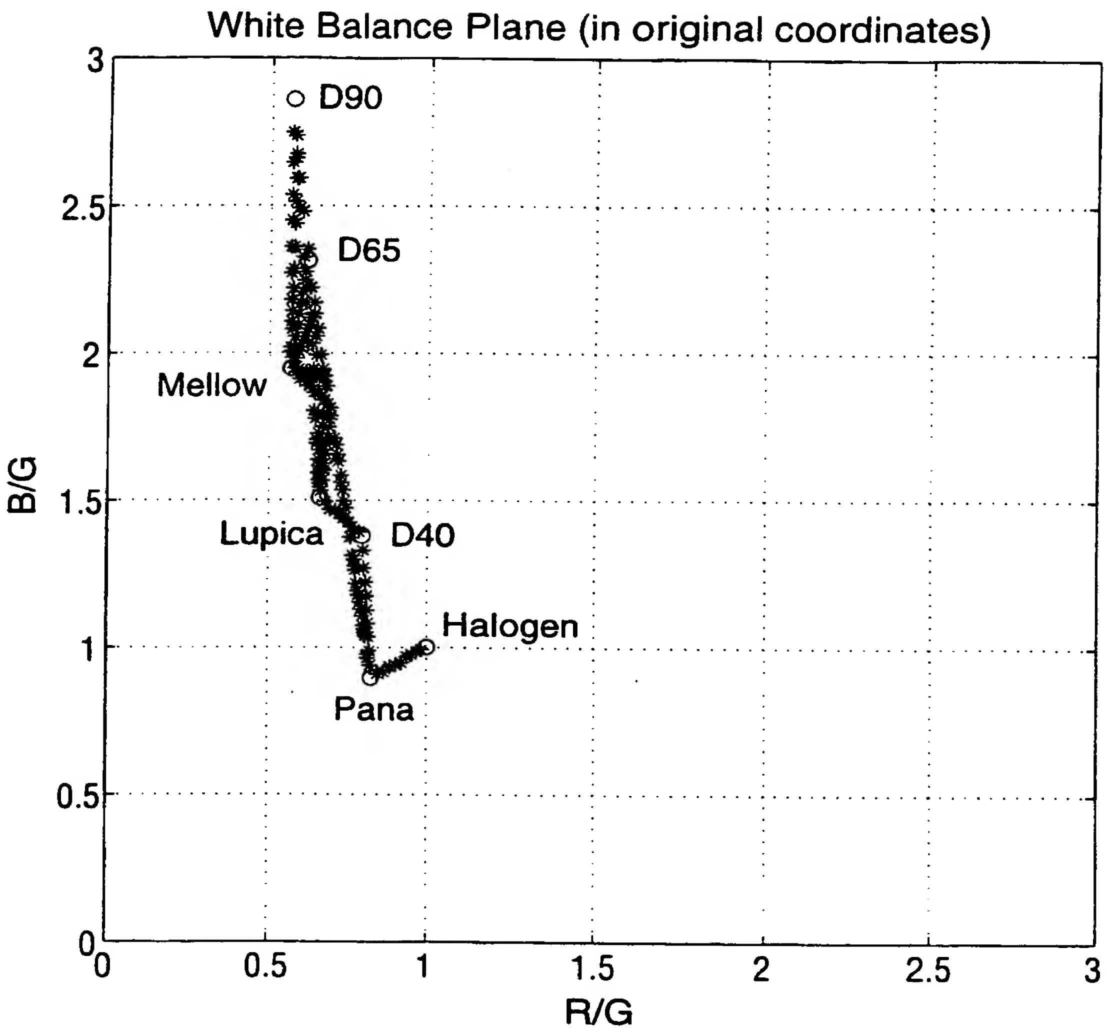

White Balance Plane (in original coordinates)
B/G
R/G
D90
D65
Mellow
Lupica
D40
Halogen
Pana
0
0.5
1
1.5
2
2.5
3

FIG. 11

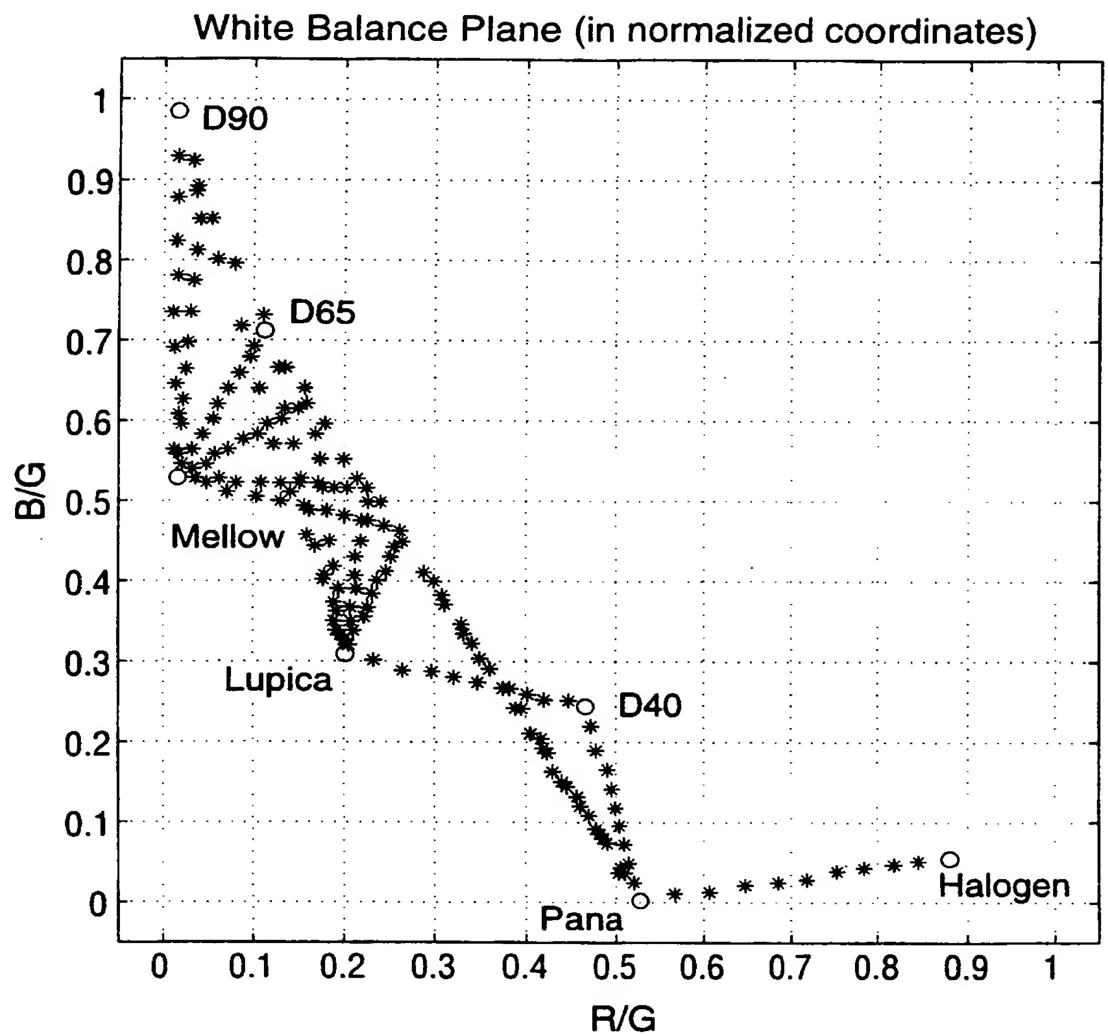

White Balance Plane (in normalized coordinates)
B/G
R/G
D90
D65
Mellow
Lupica
D40
Pana
Halogen
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

FIG. 12

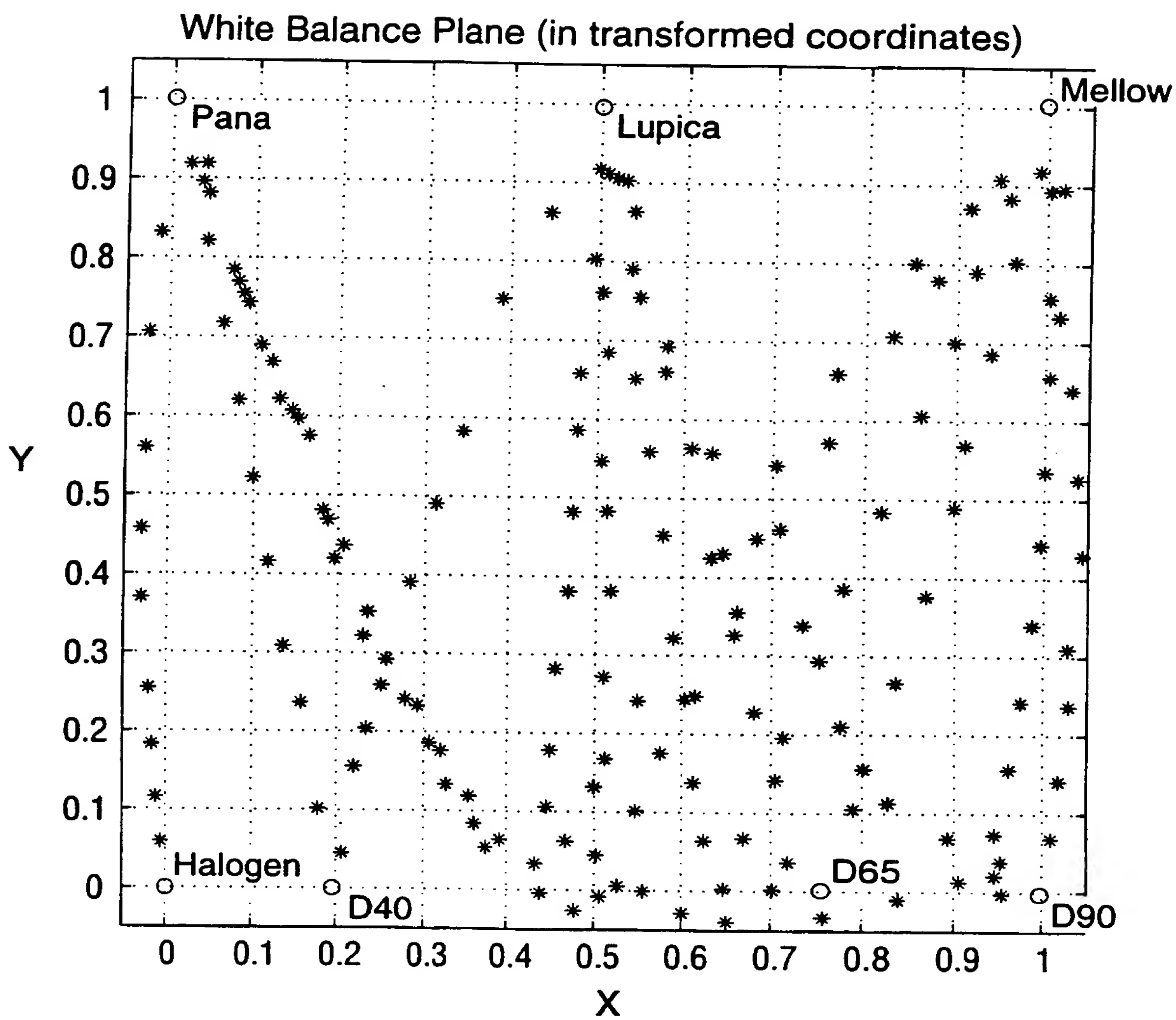

White Balance Plane (in transformed coordinates)
Y
X
Pana
Lupica
Mellow
Halogen
D40
D65
D90
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

FIG. 13